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MESOZOIC-CENOZOIC STRATIGRAPHY OF THE NORTHERN INTERIOR PLAINS AND PLATEAUX, NORTHWEST TERRITORIES

J. Dixon

1999

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J. Dixon

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Cover Illustration
Campanian-Maastrichtian Mason River Formation (light grey) unconformably overlying Albian Horton River Formation (dark grey); Horton River, Northwest Territories

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PREFACE

This study of the Mesozoic and Cenozoic strata of the Interior Plains and plateaux of western mainland Northwest Territories is a comprehensive review of our knowledge of these rocks. The study covers a large area, extending from just south of Mackenzie Delta, to the Alberta–Northwest Territories boundary. New correlations are proposed, leading to a better understanding of the stratigraphy and paleogeographic reconstructions. This comprehensive review will be a valuable aid to planning exploration programs and assessing the hydrocarbon potential of these rocks.

M.D. Everell
Assistant Deputy Minister
Earth Sciences Sector

PRÉFACE

Dans la présente étude, les strates du Mésozoïque et du Cénozoïque des Plaines et plateaux intérieurs de la partie continentale occidentale des Territoires du Nord-Ouest sont examinées en profondeur à la lumière de nos connaissances. Cet examen porte sur une vaste région s'étendant du sud du delta du Mackenzie jusqu'à la limite entre l'Alberta et les Territoires du Nord-Ouest. On propose de nouvelles corrélations, ce qui conduit à une meilleure compréhension de la stratigraphie et permet la reconstitution de la paléogéographie. Cet examen exhaustif sera une aide précieuse lors de la planification de programmes d'exploration et de l'évaluation du potentiel en hydrocarbures de ces roches.

M.D. Everell
Sous-ministre adjoint
Secteur des sciences de la Terre

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MESOZOIC–CENOZOIC STRATIGRAPHY OF THE NORTHERN INTERIOR PLAINS AND PLATEAUX, NORTHWEST TERRITORIES

ABSTRACT

Large areas of the Northern Interior Plains and plateaux are covered by a thin veneer of Cretaceous and Tertiary rock. The thickest sucessions are present in foredeeps adjacent to the mountain front, under Peel Plateau, Mackenzie Plain and the Liard Plateau. In these areas strata are between 1500 and 2000 m thick; elsewhere in the plains the succession is generally less than 500 m thick.

Over most of the Interior Plains and plateaux the succession starts with an Upper Aptian to Lower Albian transgressive, generally sandy, unit, followed by a series of alternating shale- and sandstone-dominated formations that extend into the Paleocene. Only in the extreme north, under Horton Plain, are there older, Jurassic, strata. Unconformities divide the succession into several transgressive–regressive cycles of sedimentation that can be correlated throughout the study area.

In general, the Albian to Paleocene sedimentary history is one of gradual infilling of the foreland and cratonic basins. The infilling was accompanied by the northward and southward regression of the cratonic seaway that once extended throughout western North America during much of the Cretaceous. Marine sedimentation continued until about the end of Cretaceous time (late Maastrichtian), after which the stratigraphic record is dominated by nonmarine strata.

Potential hydrocarbon source rocks occur in Albian and Upper Cretaceous strata, especially in Cenomanian–Turonian rocks. Maturity levels are generally low, but where the succession is thick, maturity increases to within the oil window. Several sandstone-rich intervals have good reservoir potential, especially the transgressive sandstones at the base of the Cretaceous succession. A significant gas recovery was made in the basal sandstone at the Arrowhead B-41 well, in Great Slave Plain.

RÉSUMÉ

De vastes régions de la partie septentrionale des Plaines et plateaux intérieurs sont couvertes d'un mince placage de roches du Crétacé et du Tertiaire. Les successions les plus épaisses se rencontrent dans les avant-fosses jouxtant le front montagneux, sous le plateau de Peel, la plaine du Mackenzie et le plateau de la Liard. Dans ces régions, l'épaisseur des strates varie entre 1 500 et 2 000 m; elle est généralement inférieure à 500 m ailleurs dans les plaines.

Sur la presque totalité des Plaines et plateaux intérieurs, la succession débute par une unité transgressive, généralement sableuse, qui s'échelonne de l'Aptien supérieur à l'Albien inférieur, laquelle est suivie d'une série de formations à prédominance de shale ou de grès qui se prolongent jusque dans le Paléocène. Des strates plus anciennes du Jurassique se rencontrent uniquement dans l'extrême nord, dans la plaine de Horton. Des discordances séparent la succession en plusieurs cycles de sédimentation transgressive–régressive qui peuvent être mis en corrélation dans l'ensemble de la région à l'étude.

En règle générale, l'histoire sédimentaire de l'Albien au Paléocène comporte le remplissage progressif des bassins de l'avant-pays et des bassins cratoniques. Ce remplissage a été accompagné par la régression vers le nord et le sud de la mer cratonique qui traversait toute l'Amérique du Nord occidentale pendant une grande partie du Crétacé. La sédimentation marine s'est poursuivie jusque vers la fin du Crétacé (Maestrichtien tardif); par la suite, des strates non marines prédominent.

Des roches mères à potentiel d'hydrocarbures se rencontrent dans des strates de l'Albien et du Crétacé supérieur, tout particulièrement dans des roches du Cénomanien–Turonien. Leur degré de maturité est généralement faible, mais là où la succession est épaisse, il s'élève jusque dans la fenêtre de pétrole. Plusieurs intervalles riches en grès montrent un bon potentiel de réservoir, particulièrement les grès transgressifs

présents à la base de la succession du Crétacé. Au puits Arrowhead B-41, dans la plaine du Grand lac des Esclaves, on a récupéré des quantités significatives de gaz naturel dans le grès de base.

SUMMARY

The Northern Interior Plains and plateaux occupy an area that extends from the Northwest Territories boundary with Alberta and northeast British Columbia, northward to Amundsen Gulf (Bostock, 1970). To the east lies the Canadian Shield and to the west, the mountains of the Cordillera. Underlying this large area is a thin veneer of Cretaceous and Tertiary strata. Most of the area is underlain by less than 500 m of Cretaceous and Tertiary rocks, but in the foredeeps under Peel Plateau, Mackenzie Plain, and Liard Plateau, 1500 to 2000 m of Cretaceous to Tertiary strata are preserved.

Deposition on the craton was in a number of shallow basins, such as Anderson and Great Bear basins, separated by broad, low-amplitude positive zones. The cratonic basins merge westward into deeper and narrower foreland basins adjacent to the Cordillera, such as the Peel Trough and Liard Basin.

Most of the preserved strata are Albian units; the Upper Cretaceous rocks are less extensively preserved and the Lower Tertiary beds even more areally restricted. The latter are preserved mostly in the Mackenzie Plain area, with a few outliers on Horton Plain. Strata as young as Pliocene are recognized on Horton Plain, whereas the youngest Tertiary strata in Mackenzie Plain are Paleocene.

Only minor modifications to the established stratigraphic nomenclature are proposed, with one new unit being designated (the Albian Mahony Lake Formation in Great Bear Plain). The Martin House and Arctic Red formations, originally designated for Albian units of the Peel Plain and Plateau areas, are correlated into Albian strata of Mackenzie Plain and Great Bear Plain. In Great Slave Plain the predominantly Albian succession is correlated with the Fort St. John Group, but its constituent formations are not always readily identified, because of at least two, significant unconformities within the succession.

Over most of the area, the succession begins with an Upper Aptian to Lower Albian transgressive sandy unit. In only a few areas is this unit absent, either because of nondeposition or younger erosional events. For example, under most of the southern Great Slave Plain this unit was not deposited and in central Mackenzie Plain, Albian strata have been eroded on the axis of the Keele Arch. The overlying Albian to Tertiary succession consists of alternating shale- and sandstone-dominant formations. However, a number of unconformities divide the succession into a series of basin-wide transgressive–regressive (TR) cycles. These TR cycles record the gradual infill of the foreland and cratonic basins, and the overall withdrawal of the interior seaway that once covered much of the interior of western North America during the Cretaceous. Cretaceous to Tertiary xenoliths in kimberlite pipes on the Canadian Shield indicate that this seaway extended much farther east than was once thought. The last record of extensive marine sedimentation is in lower Maastrichtian strata; subsequent deposits are predominantly nonmarine.

Several intervals with good potential as hydrocarbon source rocks have been identified. In the Great Slave Plain area, an oil-prone, organic-rich (up to 3.2 per cent by weight of organic carbon) interval in the Albian (Garbutt Formation) directly overlies the basal sandstone. Cenomanian to Turonian shales (Slater River Formation, Fish Scales Bed) have a high organic-carbon content (up to 8 per cent) and tend to be oil-prone. Santonian–Campanian shales in Horton Plain (Smoking Hills Formation) have an organic carbon content up to 12 per cent and are gas-prone. Most of the Cretaceous–Tertiary strata are immature to marginally mature over most of the area. However, in some of the thicker successions maturity extends into the oil window, and in Peel Plateau passes into the gas zone.

Potential reservoir rocks are present in a number of units, the most prospective being the transgressive, sandy beds at the base of the succession. In Great Slave Plain, such beds occur in west–northwest-trending linear features, interpreted as estuarine-fill deposits (Chinkeh Formation). At Arrowhead B-41, a very porous and permeable sandstone in such an estuarine fill tested good gas flows. Elsewhere, the basal sandstone is highly variable in reservoir character. Other potential reservoir intervals include the basal sandstone of the Slater River Formation and the Little Bear Formation in Mackenzie valley; the Mahony Lake Formation of

Great Bear Plain, and the Scatter Formation of the Liard and Great Slave Plain areas. Oil staining and oil seeps have been recorded from a number of Cretaceous sandstone units throughout the area.

SOMMAIRE

La partie nord des Plaines et plateaux intérieurs s'étend depuis la limite des Territoires du Nord-Ouest et de l'Alberta et du nord-est de la Colombie-Britannique vers le nord jusqu'au golfe Amundsen (Bostock, 1970). Le Bouclier canadien se trouve à l'est et la Cordillère, à l'ouest. Cette vaste région comporte un mince placage de strates du Crétacé et du Tertiaire dont l'épaisseur est presque partout inférieure à 500 m. Cependant, dans les avant-fosses du plateau de Peel, de la plaine du Mackenzie et du plateau de la Liard, l'épaisseur de ces roches atteint 1 500 à 2 000 m.

Sur le craton, la sédimentation a eu lieu dans un certain nombre de bassins peu profonds, tels que les bassins d'Anderson et du Grand lac des Esclaves, que séparaient de larges zones positives de faible amplitude. Ces bassins cratoniques fusionnent vers l'ouest en des bassins d'avant-pays plus profonds et plus étroits qui sont contigus à la Cordillère, tels la cuvette de Peel et le bassin de la Liard.

La plupart des strates conservées sont des unités de l'Albien; les roches du Crétacé supérieur sont conservées sur des étendues plus restreintes et les lits du Tertiaire moyen, sur une surface encore plus réduite. Ces derniers sont présents surtout dans la région de la plaine du Mackenzie et quelques lambeaux se rencontrent sur la plaine de Horton. Des strates aussi jeunes que le Pliocène sont reconnues sur la plaine de Horton, alors que dans la plaine du Mackenzie, les strates du Tertiaire les plus jeunes remontent au Paléocène.

On n'a proposé que des modifications mineures à la nomenclature stratigraphique existante, dont une nouvelle unité, la Formation de Mahony Lake de l'Albien, dans la plaine du Grand lac des Esclaves. Les formations de Martin House et d'Arctic Red, qui représentaient à l'origine des unités albiennes du plateau et de la plaine de Peel, ont été mises en corrélation avec des strates de l'Albien de la plaine du Mackenzie et de la plaine du Grand lac des Esclaves. Dans la plaine du Grand lac des Esclaves, la succession essentiellement albienne est mise en corrélation avec le Groupe de Fort St. John, mais les formations qui en font partie ne sont pas toujours faciles à individualiser en raison de la présence d'au moins deux discordances significatives dans la succession.

Dans la quasi totalité de la région, la succession débute par une unité sableuse transgressive qui s'échelonne de l'Aptien supérieur à l'Albien inférieur. Cette unité n'est absente que dans quelques zones, soit parce qu'elle n'y a pas été déposée, soit parce qu'elle y a été érodée. Ainsi, elle n'a pas été déposée dans la presque totalité de la partie sud de la plaine du Grand lac des Esclaves, alors que dans la partie centrale de la plaine du Mackenzie, les strates albiennes ont été érodées sur l'axe de l'arche de Keele. La succession sus-jacente de l'Albien–Tertiaire comporte des formations à prédominance de shale ou de grès. Toutefois, un certain nombre de discordances séparent la succession en une série de cycles transgressifs–régressifs qui se rencontrent à l'échelle du bassin. Ces cycles témoignent du remplissage progressif des bassin de l'avant-pays et des bassins cratoniques et du recul général de la mer intérieure qui recouvrait une grande partie de l'Amérique du Nord occidentale au Crétacé. La présence de xénolites du Crétacé–Tertiaire dans des cheminées kimberlitiques du Bouclier canadien indique que cette mer s'étendait beaucoup plus à l'est que l'on ne le pensait auparavant. La dernière période de sédimentation marine d'importance a produit les strates du Maestrichtien inférieur; les dépôts ultérieurs sont essentiellement non marins.

On a mis en évidence plusieurs intervalles présentant un bon potentiel de roches mères d'hydrocarbures. Dans la région de la plaine du Grand lac des Esclaves, un intervalle susceptible de donner du pétrole et riche en matière organique (jusqu'à 3,2 p. 100 de carbone organique), présent dans la Formation de Garbutt de l'Albien, repose directement sur le grès de base. Des shales cénomaniens–turoniens (Formation de Slater River, Lit de Fish Scales) recèlent une forte teneur en carbone organique (jusqu'à 8 p. 100) et sont susceptibles de donner du pétrole. Des shales santoniens–campaniens de la plaine de Horton (Formation de Smoking Hills) comptent jusqu'à 12 p. 100 de carbone organique et sont susceptibles de donner du gaz naturel. Dans la quasi totalité de la région, la plus grande partie des strates du Crétacé–Tertiaire sont

immatures à très légèrement matures. Toutefois, dans certaines successions plus épaisses, la maturité s'étend dans la fenêtre de pétrole et, dans le plateau de Peel, elle passe dans la zone de gaz naturel.

Des roches réservoirs potentielles se rencontrent dans un certain nombre d'unités, les plus prometteuses étant les lits sableux transgressifs situés à la base de la succession. Dans la plaine du Grand lac des Esclaves, de tels lits se rencontrent dans des structures linéaires à orientation ouest-nord-ouest et sont interprétés comme des dépôts de remplissage d'estuaire (Formation de Chinkeh). Au puits Arrowhead B-41, des essais effectués dans un grès très poreux et perméable dans un dépôt de ce type ont donné un bon débit gazeux. Ailleurs, les caractéristiques de réservoir du grès de base sont très changeantes. D'autres intervalles de roches réservoirs potentielles sont le grès de base de la Formation de Slater River et de la Formation de Little Bear dans la vallée du Mackenzie, la Formation de Mahony Lake dans la plaine du Grand lac des Esclaves et la Formation de Scatter dans la région de la Liard et de la plaine du Grand lac des Esclaves. On a observé des taches et des suintements de pétrole dans plusieurs unités de grès du Crétacé dans l'ensemble de la région.

INTRODUCTION

The Northern Interior Plains extend from the Northwest Territories boundary with Alberta and northeast British Columbia northward to the Amundsen Gulf (Bostock, 1970). The Canadian Shield forms the eastern boundary, and the mountains of the Cordillera the western one. Within this area are a number of physiographic elements (Fig. 1), defined primarily by various drainage basins and a few uplands and mountain ranges. The Mackenzie Delta and Tuktoyaktuk Peninsula are not included in the study; these areas already have been studied in detail by Dixon (1982) and Dixon et al. (1992).

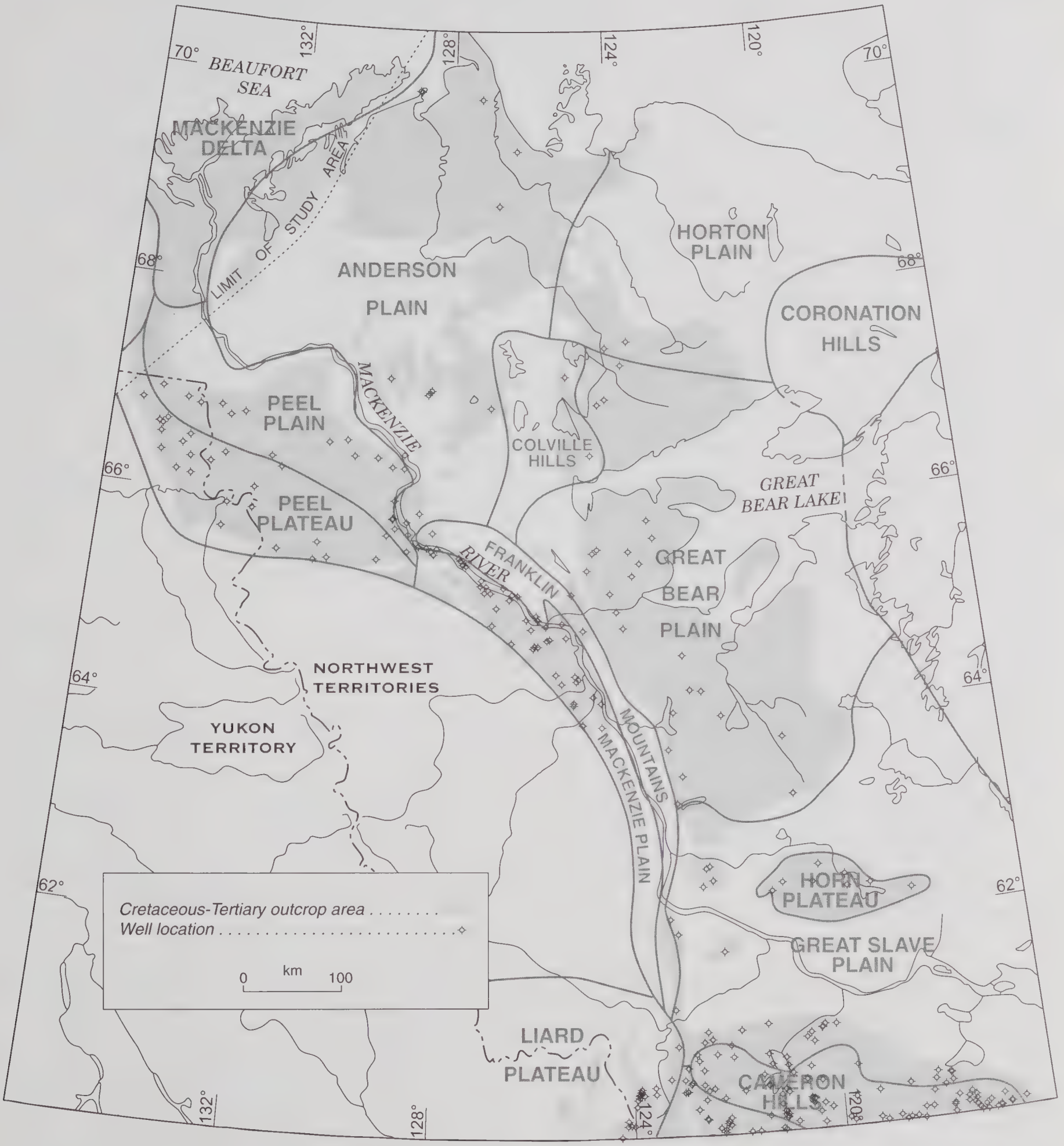

Figure 1. *Physiographic elements (after Bostock, 1970), distribution of Cretaceous and Tertiary strata, and well locations, mainland Northwest Territories.*

Previous work

A comprehensive stratigraphic account of Cretaceous and Tertiary rocks throughout the Northern Interior Plains is lacking, although a general regional account can be found in Stott and Aitken (1993). However, detailed, subregional studies have been done on large tracts of the Northern Interior Plains (e.g., Tassonyi, 1969; Yorath and Cook, 1981; Aitken et al., 1982; Williams, 1977a, b, 1978, 1989; Stott, 1960; Dixon, 1994, 1995). Geological maps of the area have been produced by Cook and Aitken (1969, 1975), Douglas (1974, 1976), Douglas and Norris (1959, 1976), Douglas et al. (1974), Norris (1981a,b,c, 1982), Aitken et al. (1982), and Yorath and Cook (1981).

Early geological expeditions into the Northwest Territories recognized the presence of Cretaceous and Tertiary rocks (see the reviews by Hume, 1954; Stott, 1960; Tassonyi, 1969) but detailed work did not begin until about the middle of the 20th century. During the Second World War the need to find oil in the Norman Wells area prompted the Canadian government to mount a major survey of Mackenzie Plain in 1942. The resulting reports were never formally published but are to be found in the archives of the Geological Survey of Canada as the "Canol Project", written in 1944 (see Hume, 1954, and Tassonyi, 1969, for the appropriate references). The Canol Project reported on the whole of the stratigraphic column, but within it there are reports on Cretaceous and Tertiary outcrops. A decade after completion of the Canol Project, Hume (1954) summarized some of the work.

Acknowledgments

A. Embry and D. Leckie reviewed the original manuscript and made many valuable suggestions. Greg Cave pointed out some correlation problems in the Old Fort Point area, which led me to re-evaluate some earlier ideas. Thanks also go to the staff of the cartographic, editorial, and document composition units at GSC (Calgary) for their fine work in producing this bulletin.

Objectives

This study aims to integrate all the available data on Cretaceous and Tertiary rocks into a comprehensive stratigraphic account of the area, without repeating the details found in previous work. Some new ideas on correlations and their significance in understanding the paleogeography of the area will be presented. Most of the new work is based on subsurface studies. Because of the generally poor exposure of Cretaceous and Tertiary strata throughout the entire Northern Interior Plains the subsurface data offers a far superior three-dimensional control on facies distribution and correlations. However, the published results of surface studies offer a means of comparing detailed data sets with the less detailed subsurface data.

Structural setting

A number of tectono–stratigraphic elements underlie the Interior Plains (Fig. 2), many of which are the result of Late Cretaceous to Tertiary deformation (Norris, 1983; Yorath and Cook, 1981). However, a number of structures had their origin in older phases of deformation. The major Mesozoic–Cenozoic structurally negative features are Anderson Basin, Peel Trough, Great Bear Basin, and Liard Basin. The last two are foreland basins; Anderson Basin is a shallow cratonic basin, and Great Bear Basin seems to be the result of a combination of moderate tectonic loading on a cratonic basin. Peel Trough is a narrow, structurally depressed zone adjacent to the Mackenzie Mountains, and the base of the Cretaceous succession plunges to 4000 m below sea level very close to the mountain front on Peel Plateau (Arctic Red F-47 well, Fig. 3). Elsewhere, the base of the Cretaceous rarely exceeds depths of 1500 m subsea (Fig. 3). In the Norman Wells to Fort Norman area, the elevation of the base of Cretaceous strata changes abruptly from subsea in the Brackett Basin to above sea level to the northwest, across a zone of a projected strike–slip fault, the Brackett Fault (Williams, 1989). The Brackett and Great Bear basins appear to represent separate foreland basins, each fronted by thrust faulted mountain areas, although the latter basin is shallower and broader than the Brackett Basin and may be a tectonically modified cratonic basin. The base of the Cretaceous at the northern margin of Liard Basin is about 500 to 700 m below sea level, plunging to the south (Leckie et al., 1991, fig. 2).

The most prominent positive features are the thrust faulted Mackenzie and Franklin mountains. The Keele Arch links the two mountain zones, but is aligned slightly oblique to the thrust and foldbelt trends, and underlies part of Brackett Basin. The Keele Arch was uplifted during Cretaceous–Tertiary deformation but may have its roots in older phenomena (Williams, 1989). Two broadly positive and westerly oriented elements are readily seen on a structure contour map of the base of the Cretaceous succession (Fig. 3). In the north, one of these elements separates Anderson Basin from Peel Trough and Great Bear Basin, and coincides with the Carnwath Platform. In the south, centred over Horn Plateau, is the other broad positive element, separating Great Bear Basin from the Liard Basin and the northern end of the Western Canada Sedimentary Basin.

Isopach, preservational, and facies trends (see later discussion) indicate that Cretaceous deposition extended from the Mackenzie Delta area, southward through the

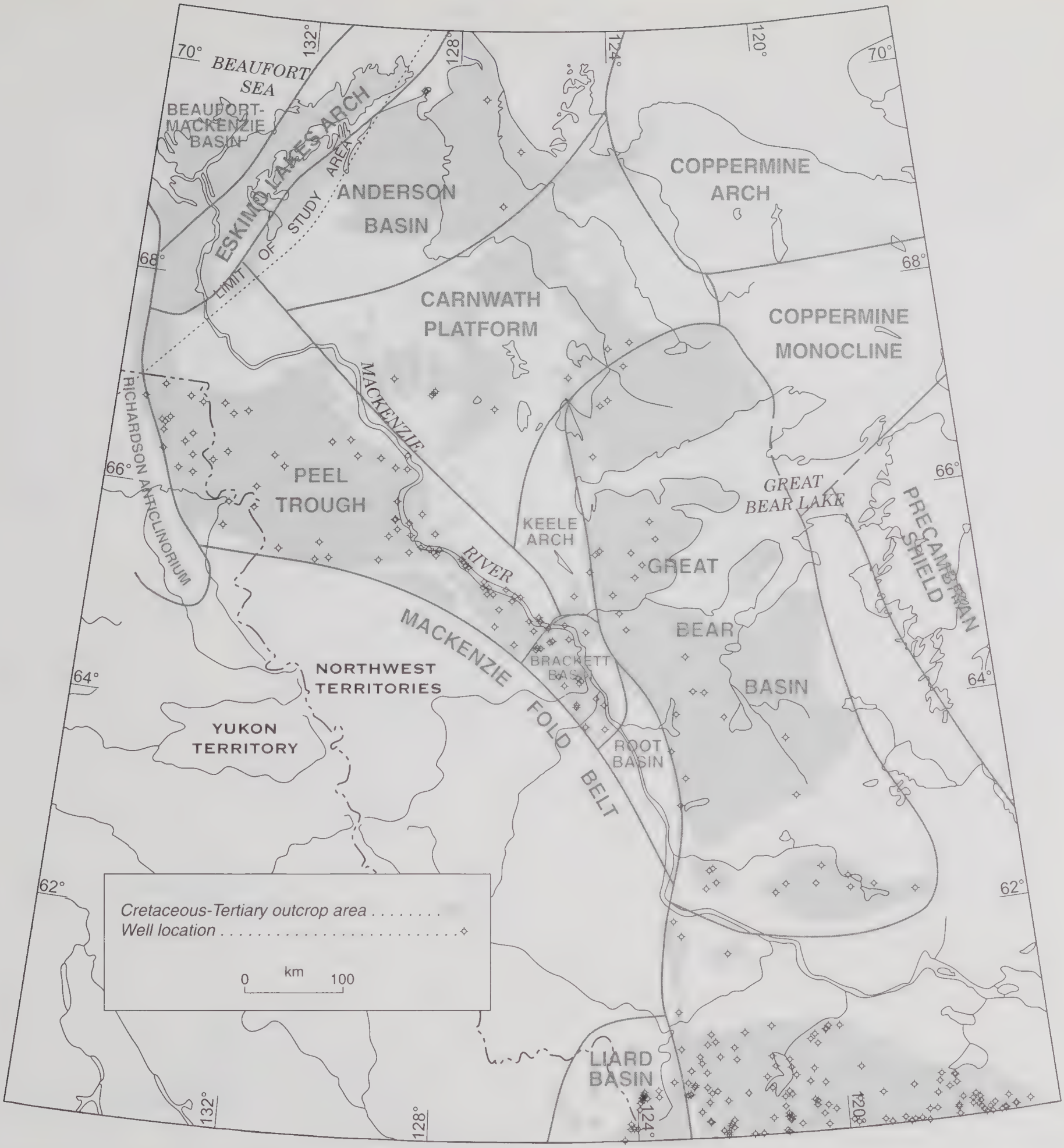

Figure 2. *Tectonic elements of mainland Northwest Territories (modified after, Norris, 1983; Yorath and Cook, 1981).*

Northern Interior Plains, to the Liard Basin and farther south. Adjacent to the mountain front, foreland basins developed, laterally merging into a more cratonic setting to the east and northeast. However, erosion of Albian strata under Brackett Basin and a large-scale positive element between Liard Basin and Peel Trough indicate that the foreland basin was not always continuous during the Cretaceous.

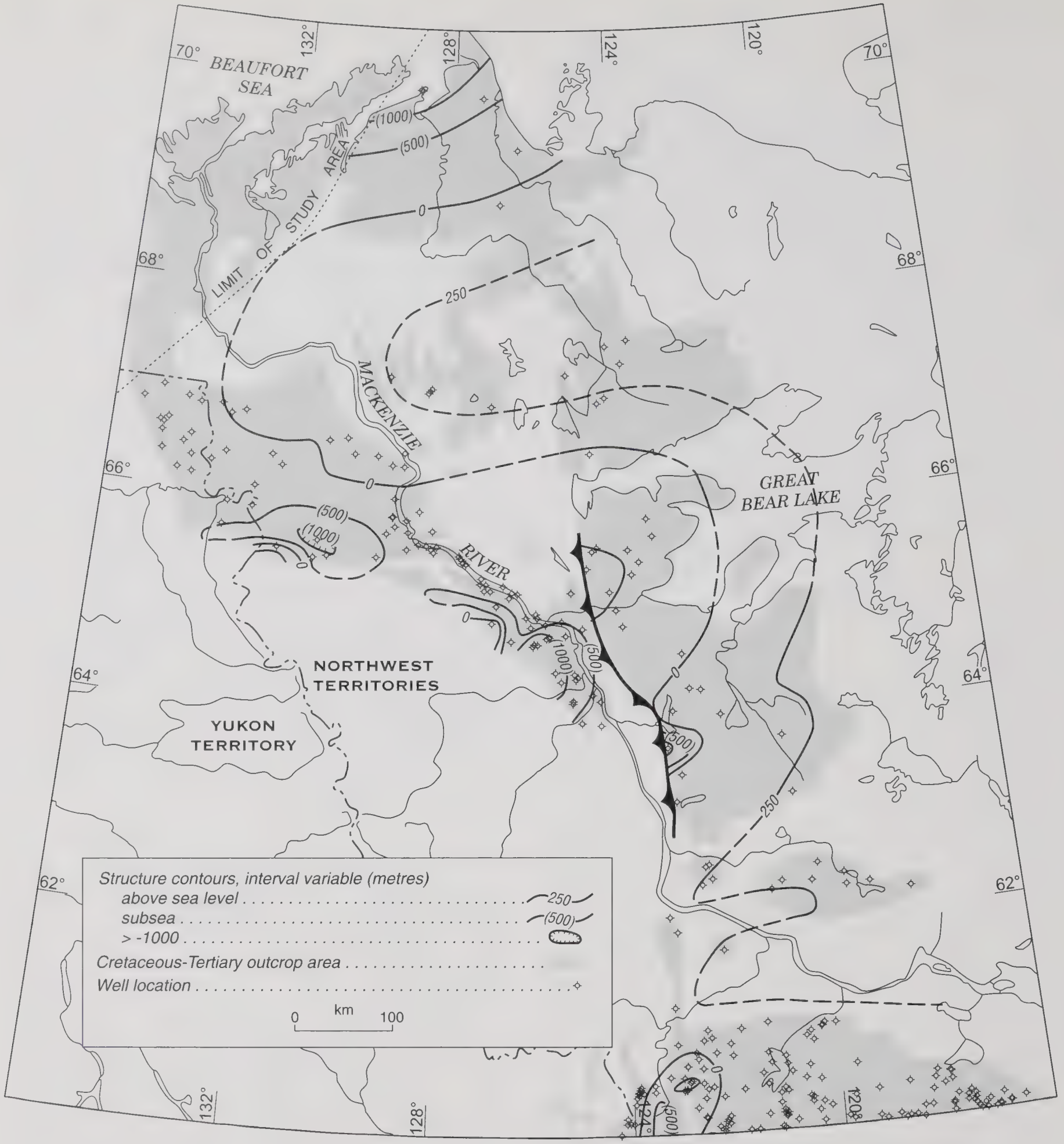

Figure 3. *Structure contours on the base of the Cretaceous succession.*

STRATIGRAPHY

Introduction

Cretaceous–Tertiary strata are widespread, but thinly developed, throughout much of the Northern Interior Plains (Fig. 4). More than 200 wells penetrate Cretaceous and/or Tertiary strata in the Northern Interior Plains (Dixon, 1997), the greatest concentration being in southern Great Slave Plain. The Upper Aptian to Tertiary succession rarely exceeds 2000 m in thickness. The thickest known section is in the Arctic Red F-47 well, on southeast Peel Plateau, where

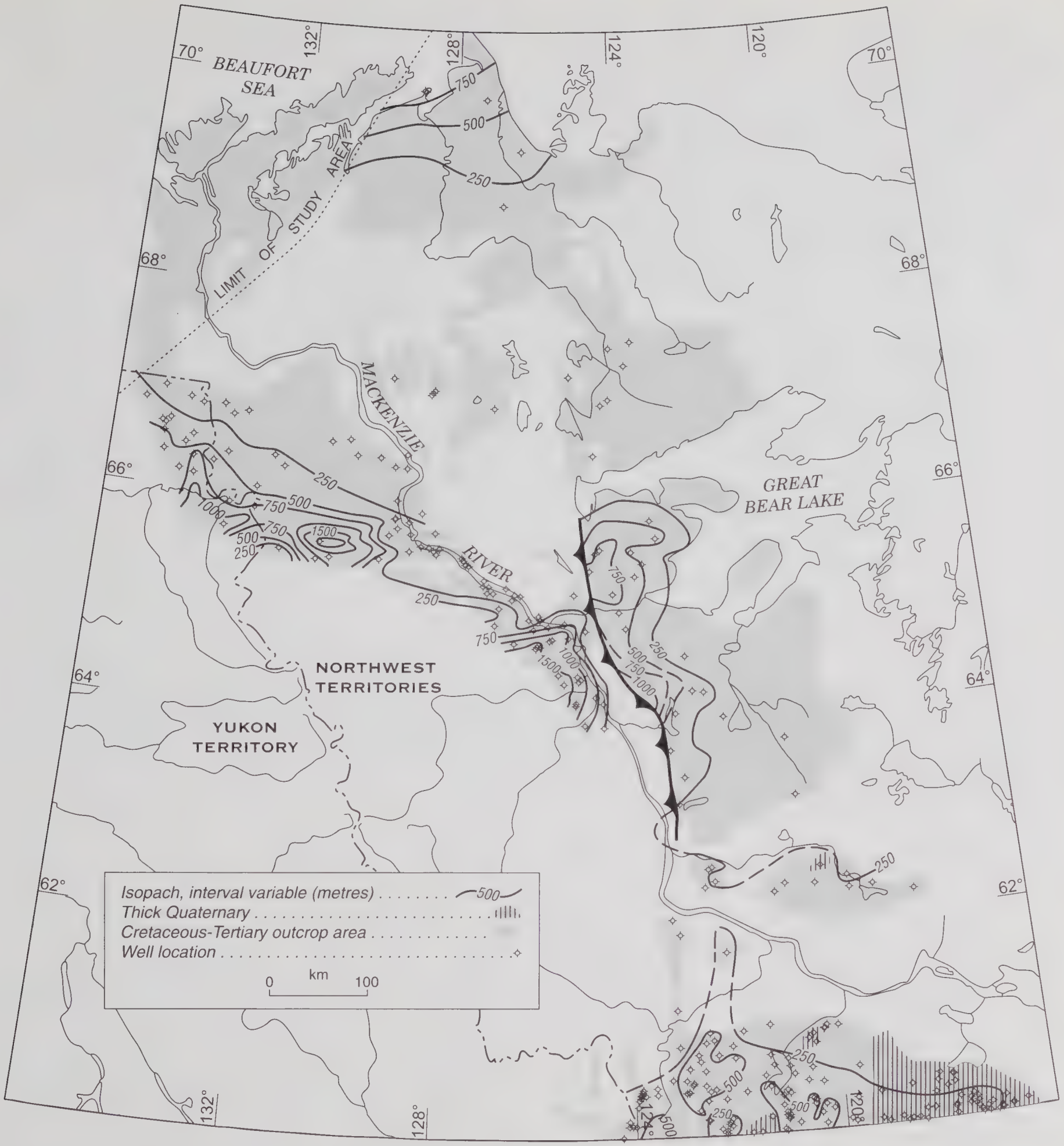

Figure 4. *Isopach map of Jurassic to Tertiary strata (may include some Quaternary - although these beds are generally thin). Jurassic present only in Anderson Basin.*

2178 m of Albian to Upper Cretaceous strata are present, although there may be some minor repetition of strata due to small-offset thrusts. Other areas of relatively thick accumulations include the Mackenzie Plain, where upwards of 1750 m of strata are preserved (Tate J-65), and in the Liard Plateau, where there are between 1500 and 2000 m of strata preserved. Strata thin rapidly away from the mountain front, and on the Interior Plains are generally between 300 and 800 m thick.

Almost everywhere within the Northern Interior Plains the Mesozoic succession begins with Upper Aptian–Lower

Albian strata resting unconformably on Paleozoic rocks. The exceptions are: a Kimmeridgian (Upper Jurassic) succession in the Horton River G-02 well (Brideaux and Fisher, 1976) in Horton Plain, and a narrow band of Jurassic and lowermost Cretaceous strata under Tuktoyaktuk Peninsula, southern Mackenzie Delta and the northwesternmost fringe of Peel Plateau. In all of these areas, the Jurassic and lowermost Cretaceous strata are erosional remnants and basin-margin equivalents of the much thicker Jurassic to Lower Cretaceous succession to the north and west (Dixon, 1982, 1992). In the present study only the Horton River G-02 occurrence will be discussed.

Tassonyi (1969) suggested that lowermost Cretaceous strata are present in the Norman Wells area, based on some tenuous paleontological data. However, the regional setting and correlations indicate no strata older than Late Aptian, and the reported older fossils are almost certainly reworked into Aptian–Albian beds. Although not located in the Interior Plains, an inlier of Cretaceous rocks within the Mackenzie Mountains (Blusson, 1971) has been reported to contain lowermost to Upper Cretaceous fossils (McMechan and Thompson, 1993). However, a critical re-evaluation of the original paleontological reports (data supplied to the author by S. Gordey, 1994) reveals that only Albian and Late Cretaceous ages are identified definitively; older ones are based on long-ranging fossils, with ages that span the Early and/or Late Cretaceous.

The most widely distributed sedimentary rocks in the Northern Interior Plains are Albian, with lesser amounts of Upper Cretaceous and Tertiary strata. Upper Cretaceous strata are preserved in the Anderson and Horton plains, within the Mackenzie Valley near Fort Norman, as scattered outliers in the Colville Hills and Great Bear Plain, as a thin veneer in Great Slave Plain, and as a thicker occurrence in the vicinity of Liard River. The bulk of the Tertiary occurrences is in the Tertiary Hills, near Fort Norman (Sweet et al., 1989), with a few scattered occurrences in Anderson and Great Bear plains. At Tertiary Hills, the youngest dated strata are Paleocene (Sweet et al., 1989), whereas those on Anderson Plain are correlated to Pliocene strata.

A series of cross-sections illustrates the correlation of Cretaceous–Tertiary beds between wells in various parts of the study area (Fig. 5–14).

Stratigraphic nomenclature

Although a well established nomenclature is available for most of the Cretaceous–Tertiary rocks of the Northern Interior Plains (Fig. 15) some clarifications and modifications are proposed here. The Sans Sault Formation is modified to member status and includes strata with limited vertical and areal distribution. The modifications significantly alter the original definition and subsequent usage. The nomenclature of the Upper Aptian to Albian succession on Peel Plateau is extended into Mackenzie Plain. In Great Bear Plain only informal terms have been used for the Albian, consequently it is proposed that the nomenclature established for the Upper Aptian to Albian of Peel Plain and Plateau, and Mackenzie Plain be extended into Great Bear Plain, with the addition of a new name for a sandstone-rich Albian succession (Fig. 16).

Sans Sault Formation

The Upper Aptian to Albian Sans Sault Formation has had a checkered history. Although originally used in an unpublished Canol Project report, its first use in a formal publication was in Stewart (1945), where the strata were referred to as the Sans Sault Group. However, it was not until Tassonyi (1969) that a more formal definition was published, citing the Sans Sault Rapids area as the type locality and restricting the name to formational rank. Tassonyi (1969, fig. 8) identified the Sans Sault Formation in several wells, the most important being the Sans Sault #1 H-24, located very close to the surface type section (Fig. 17). At the H-24 well, he identified the formation from surface to 1290 ft. (393.2 m) and divided it into a basal sandstone, a middle shaly unit, and an upper sandstone, consistent with the known succession in the nearby outcrop. He identified an underlying shale unit as being partly Cretaceous and partly Devonian (Imperial Formation). Regional correlations indicate that the shale is entirely within the Devonian Imperial Formation, with no Cretaceous involved.

Yorath and Cook (1981) and Aitken et al. (1982) gave more details of the type area. Aitken et al. (1982) restricted the usage of the name to strata within the vicinity of Sans Sault Rapids. In both publications the Sans Sault Formation is shown to pass laterally into the Arctic Red and Martin House formations. For reasons unknown, Yorath and Cook (1981, p. 23) and Aitken et al. (1982, p. 31) included shale between log depths 1290–1408 ft. (393.2–428 m) in the Sans Sault #1 H-24 well within the Sans Sault Formation. This shale was not incorporated in the Sans Sault Formation of the H-24 well by Tassonyi (1969, fig. 8). As previously stated, correlations between wells in this area strongly favour this shale being entirely Devonian.

Williams (1989) considered the possibility that the type section of the Sans Sault Formation contains a thrust fault, with repetition of strata. He based this notion on his interpretation that the Sans Sault Formation is equivalent only to the sandy sections at the base of the Upper Aptian–Albian succession throughout this area (i.e., Martin House and Langton Bay formations). However, the type section of the Sans Sault Formation is much thicker than these basal beds, leading Williams (1989) to speculate upon the presence of thrust repetition in the type section.

		Anderson Plain	Peel Plateau	Mackenzie Plain	Great Bear Plain	Great Slave Plain	Liard Plateau	TR Sequence
QUARTERNARY		sand/gravel	sand/gravel	sand/gravel	sand/gravel	sand/gravel	sand/gravel	
TERTIARY	PLIOCENE	IPERK SEQUENCE						10
	MIOCENE							
	OLIGOCENE							
	EOCENE							
	PALEOCENE							
CRETACEOUS	MAASTRICHTIAN			SUMMIT CREEK FM				9
		MASON RIVER FORMATION		EAST FORK FM			WAPITI FM	8
	CAMPANIAN			?				
	SANTONIAN	SMOKING HILLS FM		LITTLE BEAR FORMATION			KOTANEELEE FM	7
	CONIACIAN			?				
	TURONIAN		TREVOR FORMATION	LITTLE BEAR FM / SLATER RIVER FM / Basal Mbr	unnamed			6
	CENOMANIAN		?			DUNVEGAN FORMATION	DUNVEGAN FORMATION	5
			TREVOR FM			Fish Scales Bed	SULLY FORMATION	
	ALBIAN	HORTON RIVER FORMATION	ARCTIC RED FORMATION	Sans Sault Member / ARCTIC RED FORMATION	MAHONEY LAKE FM / ARCTIC RED FORMATION	Scatter Marker	SIKANNI FORMATION / LEPINE FORMATION	4
		LANGTON BAY FM / Crossley Lakes Mb					SCATTER FM (T / W / B)	3
		Gilmore Lake Mb	MARTIN HOUSE FORMATION	MARTIN HOUSE FORMATION	MARTIN HOUSE FM	CHINKEH FM	GARBUTT FM / CHINKEH FORMATION	2
	APTIAN							
JURASSIC		HUSKY FM						1
PRE-JURASSIC		LOWER PALEOZOIC	LOWER PALEOZOIC	LOWER PALEOZOIC	LOWER PALEOZOIC	LOWER PALEOZOIC	TRIASSIC/ PERMIAN	

FORT ST. JOHN GROUP (Great Slave Plain) / FORT ST. JOHN GROUP (Liard Plateau)

Tussock Member . . . . . T *Wildhorn Member . . . . . W* *Bulwell Member . . . . . B*

Figure 15. *Correlation chart of Cretaceous–Tertiary formations.*

The type section consists of three intervals: a basal sandstone, a middle shale-rich interval, and an upper interval of interbedded sandstone and shale (Tassonyi, 1969; Yorath and Cook, 1981; Aitken et al., 1982). Three similar lithological divisions can be recognized in nearby wells (e.g., Sans Sault #1 H-24, Fig. 17) but the upper sandy interval becomes shalier to the west and southwest of the type area (Fig. 7), as was mapped by Yorath and Cook (1981). These correlations indicate that the type section does not contain a fault-repeated succession and that the Sans Sault Formation (sensu stricto) is more extensive vertically than just the basal sandstones of the Upper Aptian–Albian succession, as was suggested by Williams (1989). This conclusion is similar to that reached by Aitken et al. (1982, fig. 20).

When the thicknesses of the three units in the type section are compared with those of the units in the nearby San Sault #1 H-24 well, it is unclear whether the units are correlatable. Aitken et al. (1982, p. 29) give the following thicknesses for the three units at the type section: basal sandstone 69 m, middle shale unit 274 m, and the upper sandstone 99 m. In the H-24 well there is a 53 m thick basal

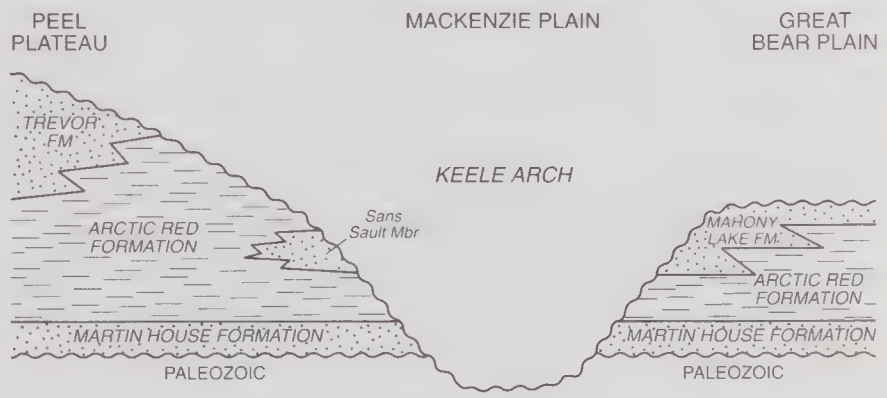

Figure 16. *Schematic representation of Upper Aptian to Albian lithostratigraphy and proposed nomenclature between Peel Plateau, Mackenzie Plain and Great Bear Plain.*

sandstone, a 101 m thick shale unit and a 240 m thick upper sandstone and shale interval (Fig. 17; also fig 8 in Tassonyi, 1969). The overall formation thickness is comparable (393 m vs. 442 m), as is the thickness of the basal sandstone. However, the other two units are not, leading to the conclusion that the upper two units in the H-24 and nearby type section are not entirely comparable. This could be due to how the base of the unit is chosen, however.

The stratigraphic relationships described above do pose a dilemma – is the Sans Sault Formation a useful term and is it worth retaining? The basal sandstone of the Sans Sault Formation is readily correlated with the widely developed Martin House Formation, and the upper two intervals could be placed within the Arctic Red Formation. This would entail abandoning the term Sans Sault Formation. Alternatively, the Sans Sault Formation could be retained as a local unit with the basal sandstone referred to as the Martin House Member. Either stratigraphic scheme would reduce the confusion as to the exact correlation of the Sans Sault beds.

However, because the Sans Sault Formation (sensu stricto) is of local significance only, the following modifications are proposed: that the Martin House Formation be extended into the Sans Sault area to include the basal sandstone of the Sans Sault Formation, the overlying shale unit be part of the Arctic Red Formation, and the upper sandstone–shale interval become a local member of the Arctic Red Formation (i.e., the Sans Sault Member; Fig. 17).

Great Bear Plain

In Great Bear Plain, the Upper Aptian to Albian succession has been divided into several informal units (Yorath and Cook, 1981; Dixon, 1994). However, the similarity between the Albian successions of Great Bear, Peel, and Mackenzie plains favours the use of a common nomenclature, hence the proposal to extend the Martin House and Arctic Red formations into Great Bear Plain. A succession of interbedded sandstone and shale overlies the Arctic Red-equivalent shales of Great Bear Plain, and will be given a new name (see later discussion). Upper Cretaceous strata are poorly known from Great Bear Plain, consequently no nomenclature will be proposed for these strata.

Figure 18 illustrates the geographic limits of the established and proposed nomenclature for the Albian succession.

Anderson and Horton plains

Anderson and Horton plains extend from the Mackenzie River in the west and southwest to the Coronation Hills in the east. To the south are the Colville Hills and the northern edge

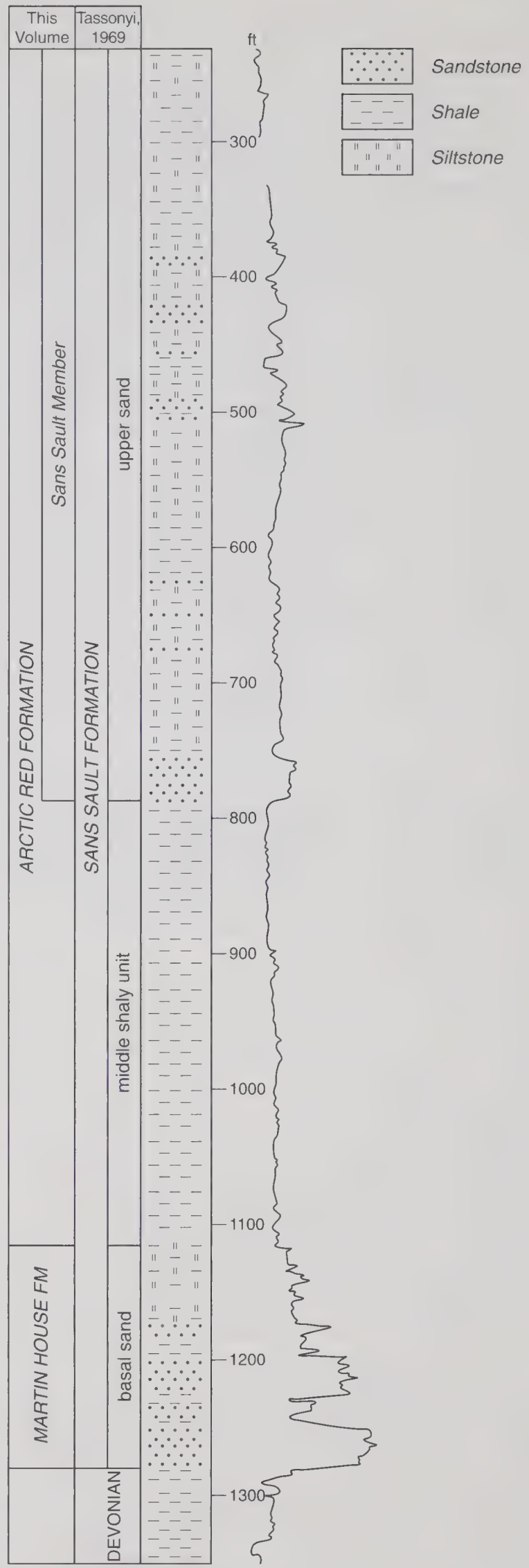

Figure 17. *Electrical log response and revised stratigraphic divisions in Upper Aptian and Albian strata in the Sans Sault #1 H-24 well.*

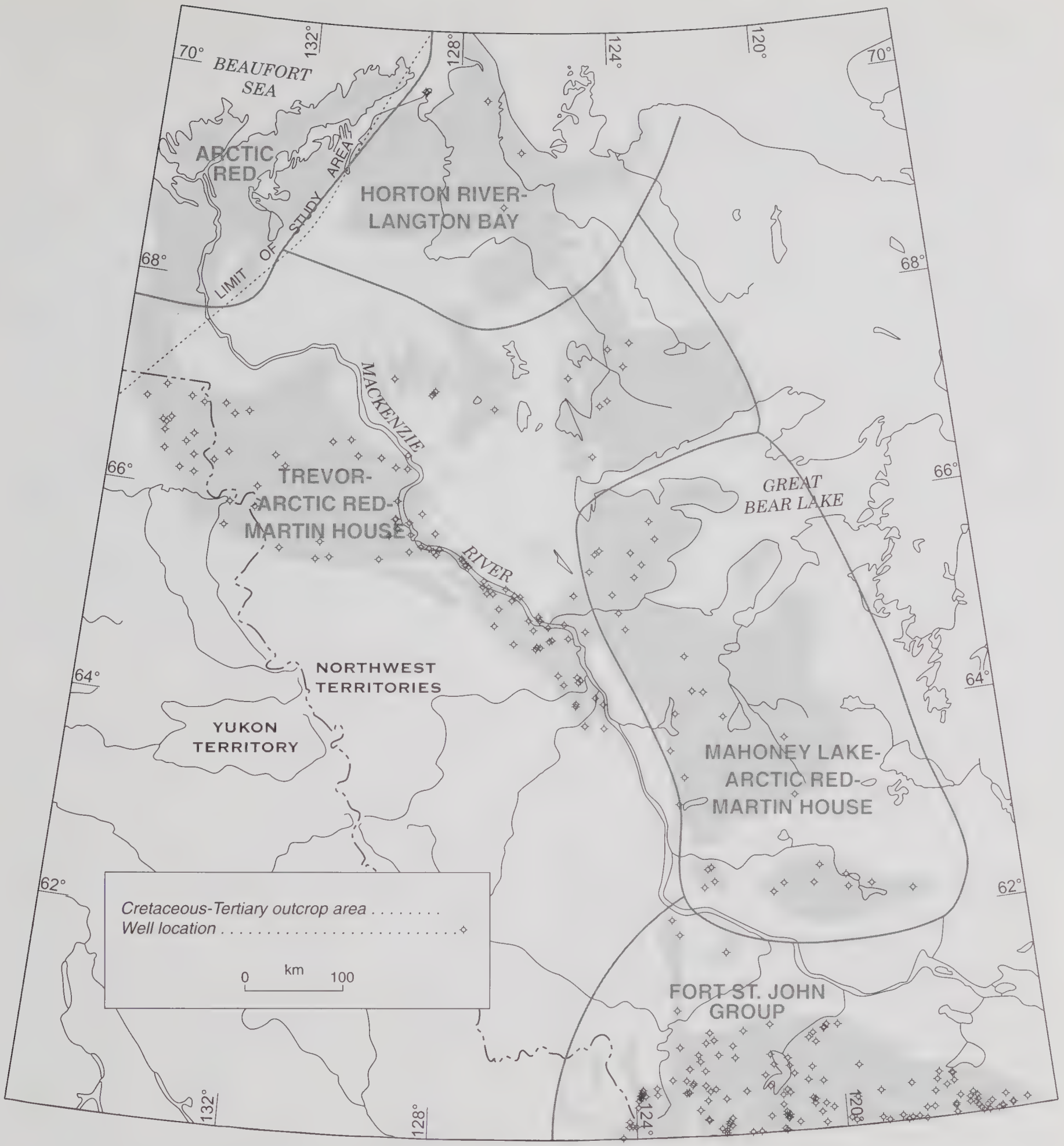

Figure 18. *Geographic limits for the use of various Upper Aptian and Albian stratigraphic names.*

of Great Bear Plain. Cretaceous strata occurring close to Mackenzie River, commonly present in a series of uplands (see fig. 3 in Duk-Rodkin and Hughes, 1994), are more appropriately compared with those of Peel Plain. The northern margin is Amundsen Gulf and to the northwest is Mackenzie Delta. Anderson, Horton and Kugaluk rivers are the main drainage systems within the plains.

Yorath et al. (1969) published informal names for Cretaceous strata in the Anderson and Horton plains area, followed later by formalized terminology (Fig. 15; Yorath et al., 1975). The formations they identified are: Langton Bay, Horton River, Smoking Hills and Beaufort. In the case of the Beaufort Formation, the use of the name has been discontinued on the mainland and the unit now is equated to

the Pliocene Iperk Sequence of the Beaufort–Mackenzie Basin (Dixon et al., 1992).

In outcrop, the oldest Mesozoic unit is the Upper Aptian to Lower Albian Langton Bay Formation, resting unconformably on Paleozoic rocks. However, Brideaux and Fisher (1976) identified Kimmeridgian (Jurassic) strata in the Horton River G-02 well.

The Cretaceous–Tertiary stratigraphy of the Anderson and Horton plains is based primarily on surface studies; only four wells have penetrated Cretaceous strata: the Horton River G-02, Smoking Hills A-23, Nicholson G-56, and Nicholson N-45. However, a complete set of geophysical logs through part of the succession is available only for the Horton River G-02 well; the others have cuttings samples and a limited suite of geophysical logs. Although the Stopover K-44 well is located on mapped Cretaceous rocks (Yorath and Cook, 1981) the cuttings samples indicate that it penetrated a thin veneer of Quaternary sand and gravel resting directly on Paleozoic rocks. It is quite probable that much of the eastern area mapped as being underlain by undifferentiated Cretaceous strata by Yorath and Cook (1981), and which extends into the northern Great Bear Plain, could be mostly Quaternary.

Jurassic (Husky Formation)

In the Horton River G-02 well, between well depths 1530 and 1816 ft. (466.3–356.6 m), Brideaux and Fisher (1976) identified Kimmeridgian dinoflagellates. This is the only known location in the study area with Mesozoic strata older than Late Aptian, and the fossil data clearly point to a major unconformity between Kimmeridgian and Upper Aptian strata within the well. Brideaux and Fisher (1976) included the Jurassic strata in the Langton Bay Formation, a practice continued by Yorath and Cook (1981). But it is incorrect to include these Jurassic strata within the Langton Bay Formation because of the major unconformity, and it is herein proposed they be correlated to the age-equivalent Husky Formation, present in the subsurface under Tuktoyaktuk Peninsula and Mackenzie Delta (Dixon, 1982; Braman, 1985).

This occurrence of Jurassic strata probably reflects preservation in a small graben, or half-graben, and may be a continuation of a trend of small grabens that extends from Eglinton Island through Banks Island (Miall, 1979) onto the mainland under Anderson Plain. On Banks Island, a very similar setting is apparent. Throughout most of the island, Upper Aptian–Lower Albian strata rest unconformably on Paleozoic rocks but within the Central Banks Basin, Jurassic strata are preserved in the subsurface (Miall, 1979).

The Jurassic succession in Horton River G-02 consists of interbedded very fine to coarse grained sandstone, siltstone and shale. There is an overall fining-upward trend, although in detail there are many, minor coarsening-upward units (Fig. 19). The thickest and coarsest sandstone interval occurs at the base of the succession. Dinoflagellates and foraminifers have been recovered from this interval, attesting to its marine character.

These beds were deposited during a Late Oxfordian–Early Kimmeridgian transgression, which was a major event in the Mesozoic history of this part of northern Canada (Dixon, 1982). Under Mackenzie Delta, equivalent strata tend to be less sandy; the basal Husky beds commonly are shale, although locally a thin basal sandstone may be present (Dixon, 1982; Braman, 1985). This contrast in the lithological succession is interpreted as indicating that the Horton G-02 locality was closer to the Kimmeridgian shoreline.

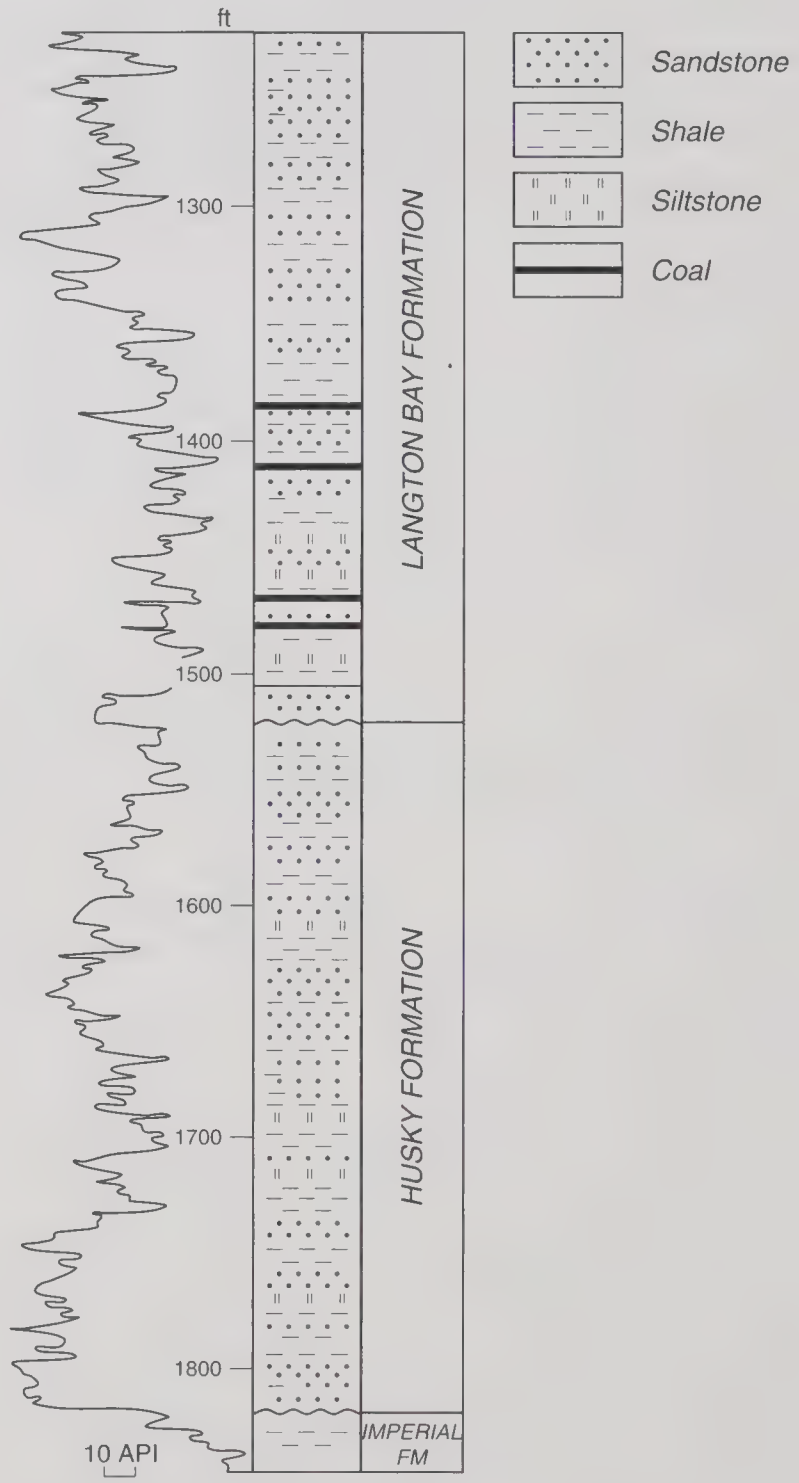

Figure 19. *Lithology and gamma-ray log response of Jurassic and Cretaceous strata in the Horton River G-02 well.*

The contact between the Langton Bay and Husky formations has been chosen to correspond to the base of a coal-bearing interval (Langton Bay Formation), immediately below which the first recorded Jurassic fossils occur.

Langton Bay Formation

The Langton Bay Formation was defined and described from Horton River by Yorath et al. (1975). It contains the Gilmore Lake and Crossley Lakes members. A Late Aptian to Middle Albian age has been determined for this unit (Yorath et al., 1975; Yorath and Cook, 1981; Doerenkamp et al., 1976; Brideaux and McIntyre; 1975).

Gilmore Lake strata consist of fine to coarse grained, locally conglomeratic sandstone, and minor interbeds of shale and coal (Fig. 19). The formation occurs throughout Anderson and Horton plains, although exposures become scattered and isolated toward the southwest. Also, there is a tendency for the strata to become finer grained and contain more interbedded shale toward the west and southwest. Large-scale crossbeds, scour-and-fill structures, and convolute laminae have been seen in outcrops. Some local topographic relief has been noted on the basal unconformity (Cook and Aitken, 1971, 1975; Yorath and Cook, 1981).

The thickness of the Gilmore Lake Member is not well documented, owing to poor exposure, but in the Horton G-02 well it is 109.7 m thick (well depths 1170–1530 ft.; 356.6–466.3 m).

Gilmore Lake strata have been interpreted as fluvial deposits that grade laterally westward and southwestward into more marine beds (Yorath and Cook, 1981).

The Crossley Lakes Member overlies Gilmore Lake strata and consists of interbedded shale, siltstone and thinly bedded sandstone. Ironstone concretions, wood debris (some logs have been noted: Yorath et al., 1969), very thin bentonite beds, and pelecypod coquinas also are present. These beds tend to weather a brownish grey. In the western and southwestern parts of Anderson Plain, Crossley Lakes beds may overlap local depressions filled with Gilmore Lake strata and rest directly on Paleozoic rocks (Yorath and Cook, 1981). In the vicinity of Kugaluk River, which is adjacent to the Eskimo Lakes Arch, the overlying Horton River Formation overlaps the Crossley Lakes Member and rests directly on Paleozoic rocks (Yorath et al., 1969). However, wherever the Horton River Formation overlies the Crossley Lakes Member the contact is abrupt. The upper contact of the Crossley Lakes Member is placed at the base of a widespread cone-in-cone bed. However, this bed is not everywhere present and along Anderson River the contact is at the base of a concretionary horizon (Yorath et al., 1969).

Thicknesses are difficult to determine because of poor exposure. Yorath et al. (1975, fig. 10) indicated 299 m of Gilmore Lake strata on one of their diagrams. In the Horton River G-02 well there are 121.9 m of Crossley Lakes strata (well depths 770–1170 ft.; 234.7–356.6 m), and in Nicholson G-56 an incompletely penetrated section is 181.1 m thick.

The only core available in strata equivalent to the Langton Bay Formation in Anderson Plain is from the Rond Lake #2 (F-56) and #5 (B-57) coreholes. These wells are located closer to Mackenzie River and the northern edge of Peel Plain than they are to the type area of the Langton Bay Formation, consequently these beds are referred to as Martin House Formation rather than Langton Bay Formation (see later discussion). Unfortunately the recovery in these small diameter (2.75") cores is very poor; of the two wells better core was recovered from the #2 well. The lithology is mostly silty to sandy mudstone with some thin sandstone beds. Oil staining is present in the sandstone and some of the silty mudstone in the core from the #2 well. A common component of the sandstone and mudstone beds is the presence of abundant carbonized wood fragments.

The Gilmore Lake Member was deposited during a Late Aptian–Early Albian transgression. The nonmarine character of the Gilmore Lake Member and its apparent infilling of paleotopography suggests deposition during an early phase of rising sea level. Continuing sea-level rise resulted in the flooding of the nonmarine environments and the subsequent deposition of marine strata of the Crossley Lakes Member.

Horton River Formation

The Horton River Formation is a Middle Albian shale-dominant succession that abruptly overlies Crossley Lake beds, or overlaps them west of Anderson River and rests directly on Paleozoic strata under Tuktoyaktuk Peninsula. As previously indicated, the contact with the underlying Crossley Lakes Member is marked by a cone-in-cone or concretionary bed. Shales of the Horton River Formation are dark grey to black, soft, fissile, and contain scattered, very thin (mm-thick) bentonite interbeds and some concretion-rich horizons. The succession is rather uniform in appearance.

Thicknesses are highly variable as a result of pre-Smoking Hills and Recent erosion. Yorath et al. (1969) cited thicknesses between 152 and 183 m, whereas in Horton River G-02 there are 228.6 m, in Smoking Hills A-23 231.7 m, and in Nicholson N-45, 239.2 m of Horton River strata. In the first two locations Horton River strata are overlain by a thin cover of Recent sand and gravel, whereas at Nicholson N-45 they are overlain by Smoking Hills Formation.

Ammonites, foraminifers and dinoflagellates have been recovered from Horton River beds, indicating its marine origin. The almost total absence of coarse siliciclastics suggests deposition well below normal wave-base, and probably beyond the influence of most storms. As will become obvious in a later discussion, the Horton River Formation was deposited on a vast shelf area within the Cretaceous interior seaway of western North America.

Smoking Hills Formation

The Santonian–Campanian Smoking Hills Formation is a highly organic-rich shale succession that derives its name from the hills adjacent to Franklin Bay, where the shales "burn" along the sea-cliffs (Fig. 20). It rests disconformably on the Albian Horton River Formation and is abruptly overlain by Mason River Formation (Fig. 21). Its area of outcrop is limited to between Franklin Bay and Kugaluk River. However, it extends westward in the subsurface under Tuktoyaktuk Peninsula (Dixon et al., 1992). In the study area the formation has been penetrated only by the Nicholson N-45 and G-56 wells. Under Tuktoyaktuk Peninsula it rests mostly on Albian shales of the Arctic Red Formation, but locally, especially on the Eskimo Lakes Arch, it rests directly on Paleozoic rocks (e.g., Kiligvak I-29).

Palynomorphs and dinoflagellates are abundant in the Smoking Hills succession and indicate a Santonian to Campanian age (McIntyre, 1974; Yorath et al., 1975; Doerenkamp et al., 1976). Although Yorath et al. (1975) and Yorath and Cook (1981) suggest that the strata are as old as Coniacian there are no definitive data to indicate an age any older than Santonian. Foraminifers are very poorly represented, consisting of a very low diversity and impoverished assemblage (D.H. McNeil, pers. comm.). Macrofossils are scarce, although fish bones and scales, and vertebrae of marine reptiles have been recovered.

Smoking Hills strata consist of black, fissile shale with thin interbeds of white to yellow weathering bentonite. In most areas the bentonites are only millimetres thick but may be up to 1 m thick locally. Yorath and Cook (1981) described rusty weathering conglomerates as part of the Smoking Hills Formation, however, re-examination of these beds indicated that these conglomerates are Recent river-terrace deposits, juxtaposed against Smoking Hills strata. Selenite crystals are a common weathering feature of the Smoking Hills Formation, occurring on outcrop surfaces.

In the type area, along Horton River, the Smoking Hills Formation can be divided into three units, based on slight variations in colour and weathering profile (Fig. 21). Dixon et al. (1992) noted that these differences are reflected in the mineralogy and organic carbon content. In the subsurface under Tuktoyaktuk Peninsula, the Smoking Hills Formation typically contains several very radioactive zones, reflected in the high gamma-ray counts through these intervals (Myhr and Barefoot, 1976; Dixon et al., 1992).

The constantly eroding sea cliffs on Franklin Bay create the right conditions for pyrite oxidation, which in turn generates sufficient heat to help cause combustion of the organic matter in the formation (Matthews and Bustin,

Figure 20. *Shales of the Smoking Hills Formation burning along sea-cliffs of Franklin Bay. GSC photo 3763-1.*

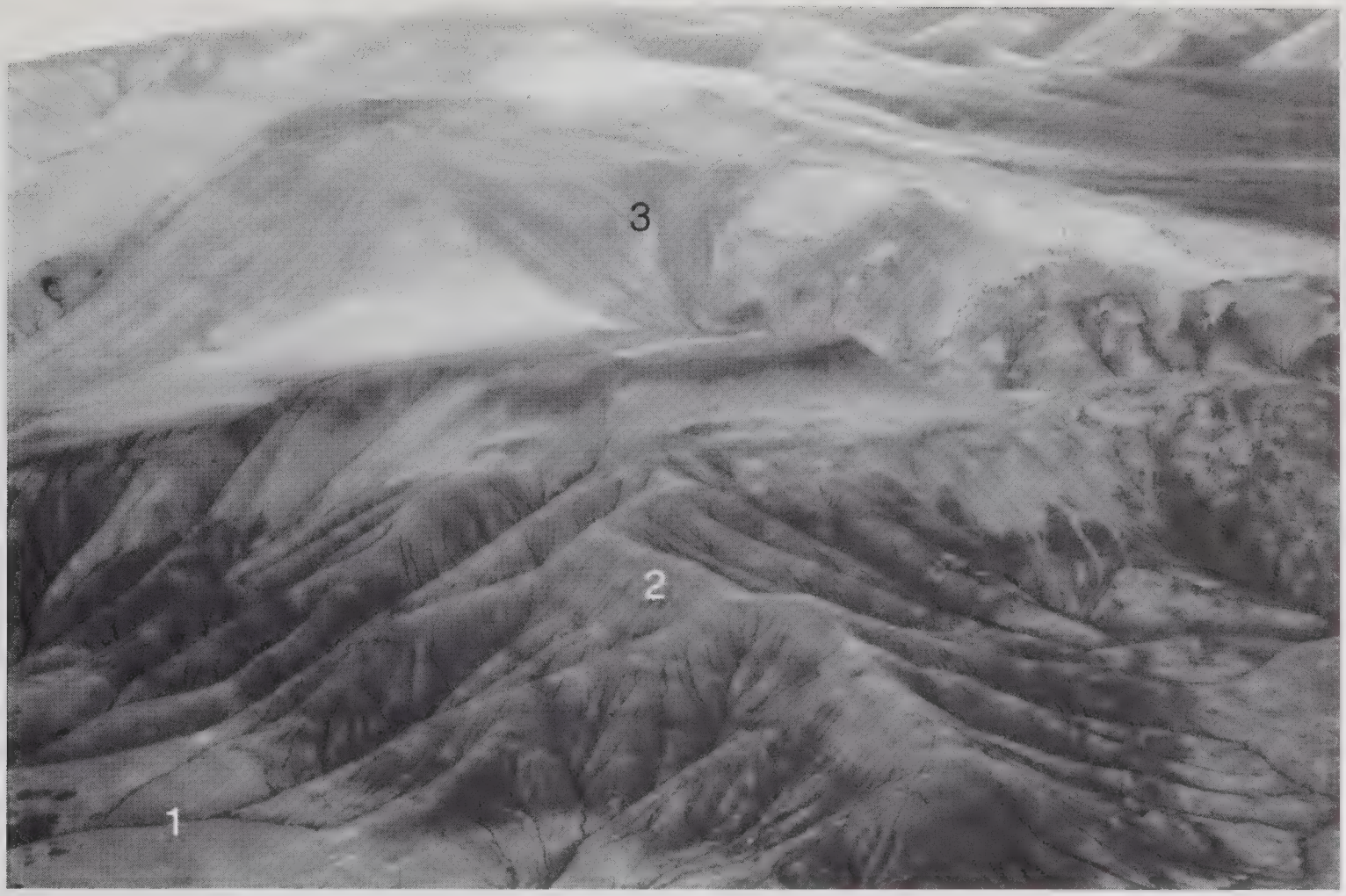

Figure 21. *Horton River (1), Smoking Hills (2), and Mason River (3) formations along Horton River. GSC photo 2236-3.*

1984). Organic matter can constitute up to 12 per cent (by weight) of the rock (Dixon et al., 1992). Consequences of the combustion are the constant pall of acrid smoke over the sea cliffs and the production of brightly coloured burnt rocks (yellow, red and orange are common). In the Anderson and Horton plains, Smoking Hills strata are between 30 and 100 m thick. In the Nicholson G-56 well they are about 50 m thick. However, under Tuktoyaktuk Peninsula strata attain thicknesses up to 500 m (Dixon et al., 1992).

The organic-rich character, shale-dominance, and distal setting (see Dixon, 1986, 1992) suggest Smoking Hills strata were deposited in a low-energy, low-oxygen environment, well below normal and storm wave-base, probably in an outer shelf, slope, and/or basinal setting.

Mason River Formation

The Campanian to Maastrichtian Mason River Formation abruptly, and disconformably, overlies the Smoking Hills Formation (Fig. 21) and in turn is unconformably overlain by locally occurring sands and gravels of the Pliocene Iperk Sequence. Along parts of Horton River, east of the location illustrated in Figure 21, the Mason River Formation rests directly on Albian strata (Fig. 22: unpublished Geological Survey of Canada paleontological reports 2-DJM-1986 and 1SPF-1984, D. McIntyre and S. Fowler, respectively). Mason River strata outcrop in a restricted area, between the Smoke and Horton rivers, with the best exposures along Horton River.

In outcrop the Mason River is a distinct light grey, in sharp contrast to the dark grey to black of the underlying Smoking Hills and Horton River formations (Fig. 21, 22). Fissile shale is the dominant lithology, with a number of horizons rich in rusty-brown weathering ironstone concretions. Yorath and Cook (1981) identified three members at the type section, the middle one rich in ironstone concretions.

It is 117 to 179 m thick in outcrop (Yorath and Cook, 1981) and 206.3 m in the Nicholson G-56 well.

The Campanian to Maastrichtian age is based principally on palynomorphs and foraminifers (McIntyre, 1974; Yorath et al., 1969, 1975; Doerencamp et al., 1976). McIntyre (1974) originally identified his palynological zone H3 as occurring in the base of the Mason River Formation ("Pale Grey Shale") but subsequent recollecting of a section along Horton River (unpublished field data by McIntyre and Dixon) revealed that much of zone H3 occurs in the top of the Smoking Hills Formation.

Mason River strata are interpeted as having been deposited below storm wave-base in a low-energy, marine

Figure 22. *Horton River Formation (1) unconformably overlain by the Mason River Formation (2). Horton River. GSC photo 4500-1.*

shelf setting, based on the presence of marine fossils, and lack of coarse-grained siliciclastic sediment. Also, the regional context favours such an interpretation (see discussion of paleogeography farther along in this bulletin; Dixon 1986, 1992).

Iperk Sequence

Weakly consolidated sandstone and conglomerate erosionally overlie the Mason River Formation on a few hills between Anderson and Horton rivers. These were correlated with the Beaufort Formation of Banks Island by Yorath et al. (1975) and Yorath and Cook (1981). Dixon et al. (1992) argued against using the name "Beaufort Formation" in the Beaufort–Mackenzie region because of the numerous incorrect usages of the name. Although lacking in age-diagnostic fossils the sandstone and gravel succession is probably equivalent to the Pliocene Iperk Sequence in the nearby Beaufort–Mackenzie Basin (Dixon et al., 1992). Iperk strata in Anderson Plain are interpreted as fluvial deposits, possibly part of a large fluviodeltaic complex, based on the abundance of sands and gravels, and the regional context of the sequence (Dixon et al., 1992),

Peel Plateau and Plain

Peel Plateau and Peel Plain lie between the Richardson Mountains in the west, Mackenzie Mountains in the south and the Mackenzie River on the east and north (Fig. 1). The main rivers crossing this area are the Peel and Arctic Red in the west and the Ontaratue and Ramparts in the east. The boundary between Peel Plain and Mackenzie Plain is located approximately near Sans Sault Rapids, where the Mackenzie River turns northward.

Underlying most of the area are Upper Aptian to Upper Cretaceous strata of the Martin House, Arctic Red and Trevor formations. In the southeastern part of Peel Plain, and extending into Mackenzie Plain, the Sans Sault Formation (sensu stricto) has been mapped (Yorath and Cook, 1981). Only at the extreme northwestern margin of Peel Plateau, north of the Dempster Highway, are older Cretaceous beds preserved. These latter areas have been summarized by Dixon (1992) and will not be dealt with in this report. Likewise, in the same area, there are scattered outcrops of the Upper Cretaceous Boundary Creek Formation (Norris, 1981a), also not included in this report. The older Cretaceous beds in the northwestern part of Peel Plateau include the Mount Goodenough and Rat River formations; these represent the basin margin deposits of the much thicker succession west and northwest of the Trevor and Eskimo Lakes fault zones (Dixon, 1992).

Martin House Formation

Originally defined by Mountjoy and Chamney (1969) from near the junction of Peel and Snake rivers, the Martin House

Formation was subsequently mapped or identified as far north as Stony Creek (Norris, 1981a; Dixon, 1992, p. 41). Within most of the wells on Peel Plateau and Plain that penetrate Cretaceous strata there is a thin basal succession of interbedded siltstone, shale and sandstone. This basal interval is correlated to the Martin House Formation. Martin House strata rest unconformably on Paleozoic rocks throughout most of the formation's area of occurrence although in the northwesternmost Peel Plateau, north of Dempster Highway, it abruptly overlies the Barremian to Lower Aptian Rat River Formation.

Martin House strata consist of interbedded siltstone, shale and thin-bedded, commonly glauconitic, sandstone. Bivalve coquinas are common, although thin. In outcrop, as well as the subsurface, the succession is commonly brownish grey. Thin coarsening-upward cycles occure in the Vittrekwa River outcrops (Dixon, 1992; northwestern Peel Plateau). These consist of shale grading up into silty shale, capped by a thin sandstone bed. Some cycles have a thin coquina bed overlying the sandstone. These cycles give the succession a banded appearance in outcrop (Fig. 23).

Mountjoy and Chamney (1969) recognized two informal members in the type area: a Basal Siltstone member and an overlying Glauconite member, with the latter overlapping the Basal Siltstone Member northward. However, this northward change in stratigraphy can be equally due to a facies change rather than an overlapping relationship. Mountjoy and Chamney (1969) also speculated on the presence of local conglomerates at the base of the Martin House Formation, based upon poorly dated outcrops and comparison with other areas. The known regional geology and the few dated occurrences (Jeletzky, 1974, p. 6) of these conglomerates strongly favour them being either part of the Upper Devonian Imperial Formation or the lower Mississippian Tuttle Formation.

In the subsurface (Fig. 5, 6) the Martin House Formation generally consists of a basal sandstone-rich interval abruptly overlain by thinly interbedded siltstone, sandstone, and shale. This twofold division is commonly reflected in the response of the geophysical logs (Fig. 5, 6), although the basal sandstone is not always readily identified. Thin beds of very fine to fine grained sandstone are present in the upper interval. In the basal interval, thick to very thick beds of fine to medium grained sandstone and, locally, thin beds of pebbly sandstone are present. The brownish colour seen in outcrops is commonly present in the cuttings samples, along with an abundance of glauconite. Core 1 from the Sainville D-08 well was cut in the Martin House Formation (Fig. 24), within the basal, sandier part of the formation, and consists of interbedded, thoroughly bioturbated sandstone and shale, with one thin conglomeratic horizon near the base of a sandstone bed. A small-diameter core was cut in Martin House-equivalent beds in the North Circle #1 A-37 well (cores 1 to 10, depth 117–183 ft.; 35.7–55.8 m), on the northeast part of Peel Plain. Although poorly preserved, the cores recovered fine to medium grained sandstone between 35.7 and 46.4 m (117–152 ft.), underlain by fissile shale. The sandstone tends to be less argillaceous below 70.1 m (132 ft.) and above this depth it is bioturbated. What appears to be oil

Figure 23. *Martin House strata (1) overlain abruptly by Arctic Red Formation (2). Vittrekwa River, northwest Peel Plateau. GSC photo 2846-8.*

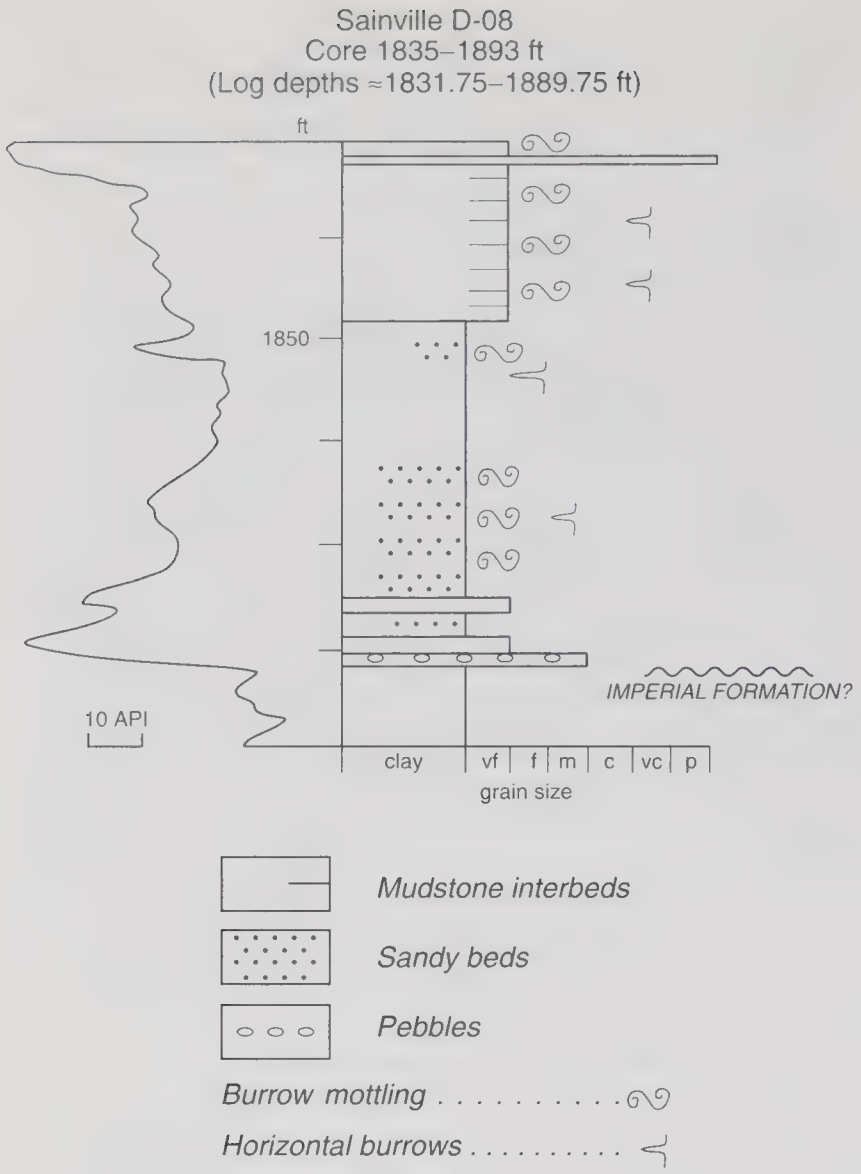

Figure 24. *Graphic representation of Martin House strata in core from the Sainville D-08 well. Reported core depth of 1835–1893 ft. adjusted to log depth 1831.75–1889.75 ft.*

staining imparts a dull brown colour to the rock. The North Circle #1 A-37 well is located about 90 km southwest of the Rond Lake wells where oil staining also is present in equivalent sandstone beds.

Martin House strata also were cored in the Hume River I-66 and N-10 wells (Fig. 25), located on eastern Peel Plain. Here the vertical succession records a coal-rich, nonmarine interval resting unconformably on Devonian shale, in turn succeeded erosionally by a channel-sandstone that grades upward into interbedded, marine sandstone and mudstone. This area of the Peel Plain is a transition area between the nonmarine to marine Langton Bay Formation of Anderson and Horton plains with the entirely marine Martin House Formation of the western Peel Plateau and Plain.

Martin House strata generally are less than 100 m thick, with the thickest sections adjacent to the eastern flank of the Richardson Mountains, thinning to the north and east (Fig. 26). Available thickness data suggest there was a thick lobe extending northeast from the southern Richardson Mountains (Peel River M-64 well contains 146.4 m, and Peel River L-01, 158.5 m, of Martin House strata), and a less well defined lobe in the vicinity of the Cranswick A-22 well (Fig. 26).

In the northern outcrops, the contact with the overlying Arctic Red Formation is abrupt (Fig. 23) and this is also reflected by the geophysical log responses (Fig. 5, 6), although Mountjoy and Chamney (1969) originally described the contact as gradational. In general, the Martin House Formation can be identified quite readily from geophysical logs, as well as by the common occurrence of glauconite in cuttings samples. However, in a few localities the Martin House succession is not well defined on geophysical logs, e.g., Peel River K-09 and K-76.

As previously discussed, in southeast Peel Plain, the use of Martin House Formation is extended to include the basal sandstone of the former Sans Sault Formation.

Foraminifers, palynomorphs, bivalves, and ammonites from the formation indicate a Late Aptian to Early Albian age (Mountjoy and Chamney, 1969; Jeletzky and Stelck, 1981, p. 11; Dixon, 1992) and attest to its marine origin. The marine character is further substantiated by the abundant occurrence of bioturbated beds, hummocky cross-stratification, and presence of glauconite.

The stratigraphic position of Martin House strata indicates deposition during a transgressive phase of sedimentation, the bulk of the sediments being deposited in a shallow-water, marine shelf. This is also indicated by the presence of crossbedded (commonly hummocky cross-stratified) and bioturbated sandy beds interbedded with silty shale, and the common occurrence of bivalve coquinas. However, in northeast Peel Plain some nonmarine, or brackish water sediments, in the form of coaly beds, were deposited. These latter deposits would be contiguous with the nonmarine beds in the Gilmore Lake Member of the adjacent Anderson Plain.

Arctic Red Formation

Mountjoy and Chamney (1969) defined and named the Albian Arctic Red Formation, with its type area in the vicinity of the confluence of Snake, Peel and Arctic Red rivers. Arctic Red strata cover a large area of Peel Plateau and Peel Plain. It is a shale-dominant succession between 350 and 400 m thick at its type section but is upwards of 1512.8 m thick in the Arctic Red F-47 well in the south-central part of Peel Plateau (Fig. 27).

Mountjoy and Chamney (1969) subdivided the Arctic Red into a number of informal local members based on the variation in the content of ironstone concretions and silty shale. In general, they noted that the amount of silty shale decreased northward, with a concomitant increase in

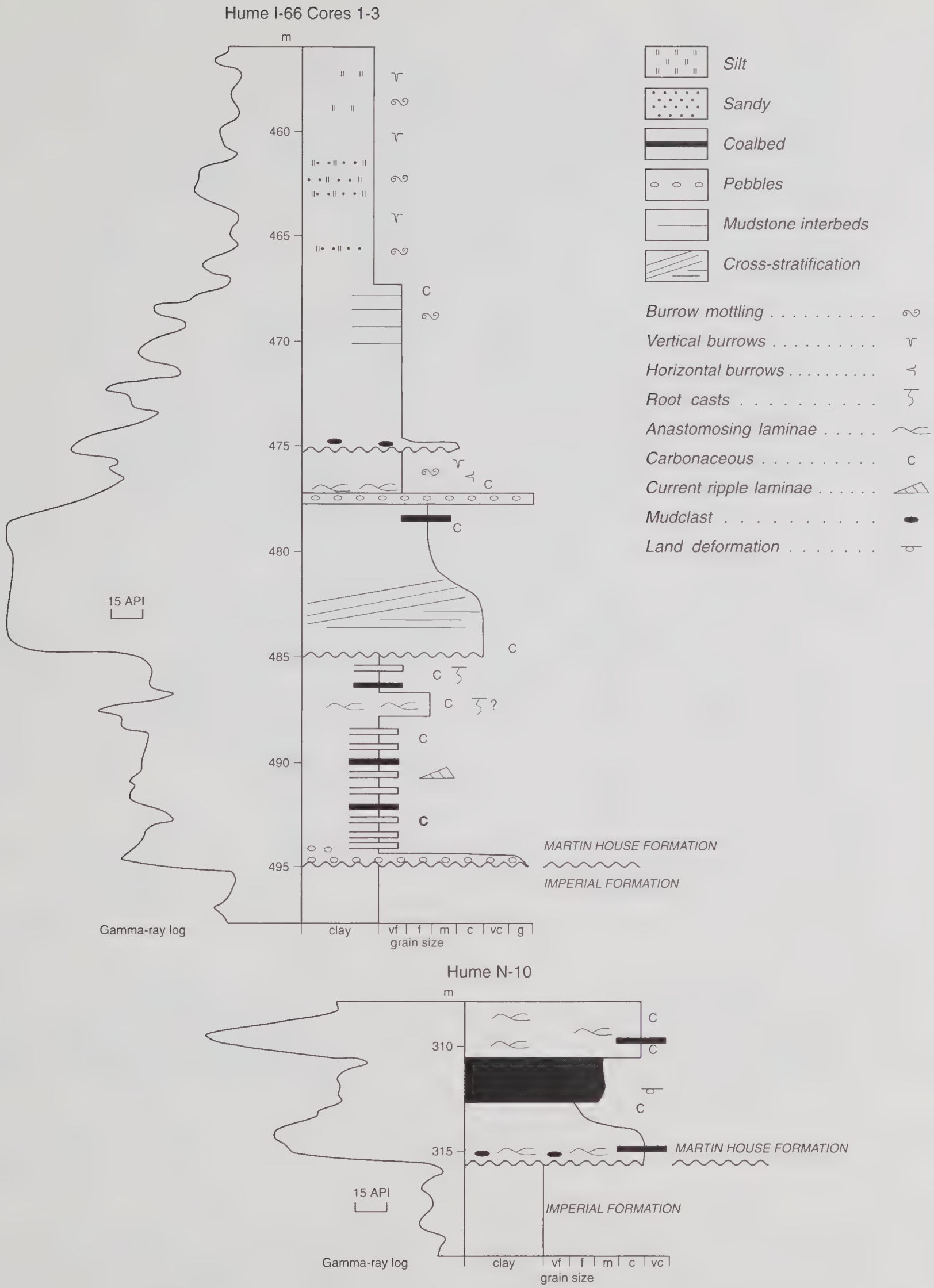

Figure 25. *Graphic representation of Martin House strata in core from the Hume N-10 and I-66 wells.*

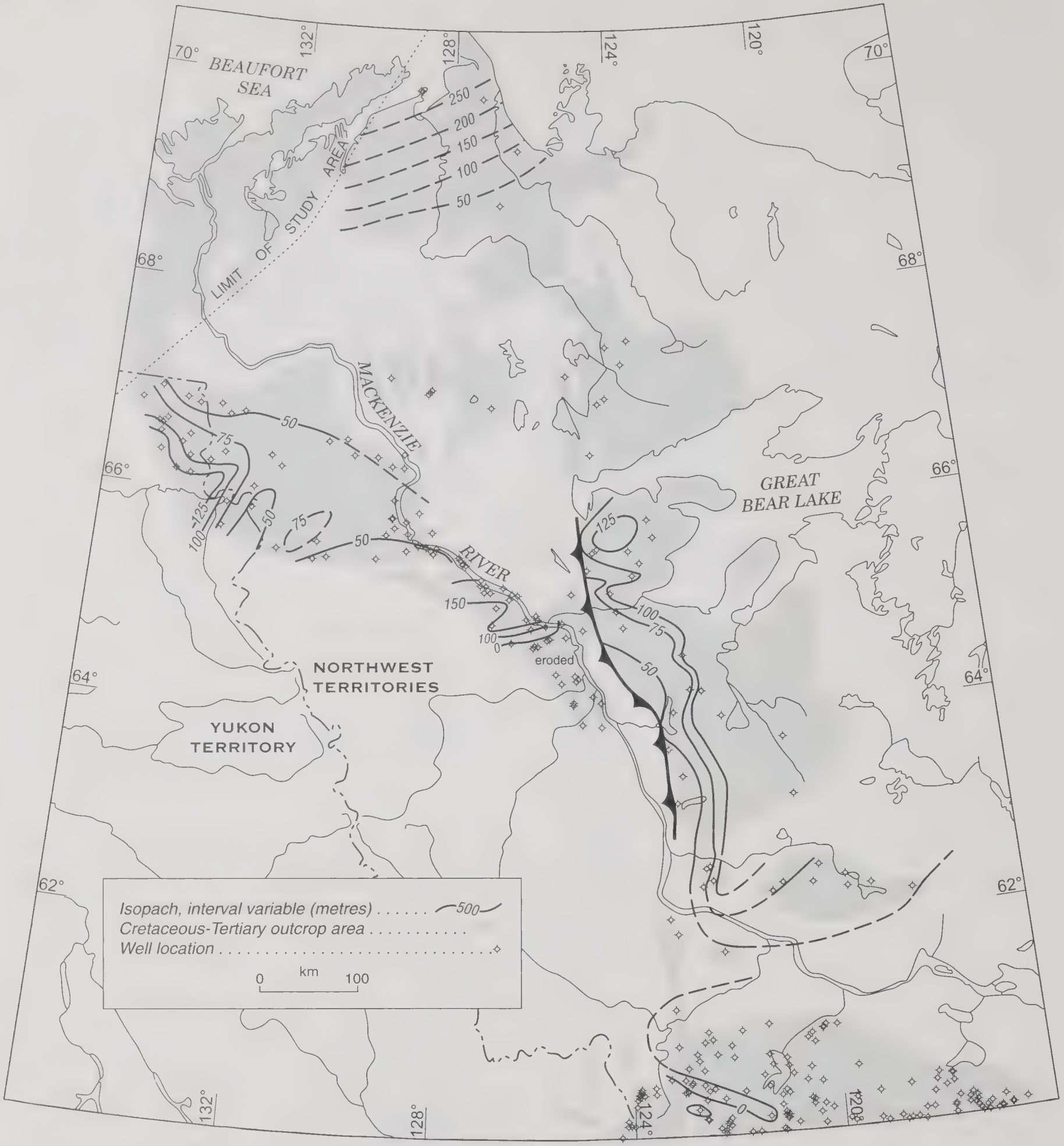

Figure 26. *Isopach map of Upper Aptian to Lower Albian strata (Martin House, Langton Bay and equivalent units).*

concretionary shale. In the subsurface there are some locally identifiable and, in some cases, correlatable log responses (Fig. 5, 6) but it is difficult to relate these to the members recognized by Mountjoy and Chamney (1969). Many of the distinct log responses appear to be caused by variations in the silt and/or sand content of the shales. The shales are dark grey to black, fissile, silty to sandy, and locally weather brownish grey. Thin beds of bentonite are scattered throughout the formation. In general, the silt and sand content increases upwards, heralding the sandy character of the gradationally overlying Trevor Formation.

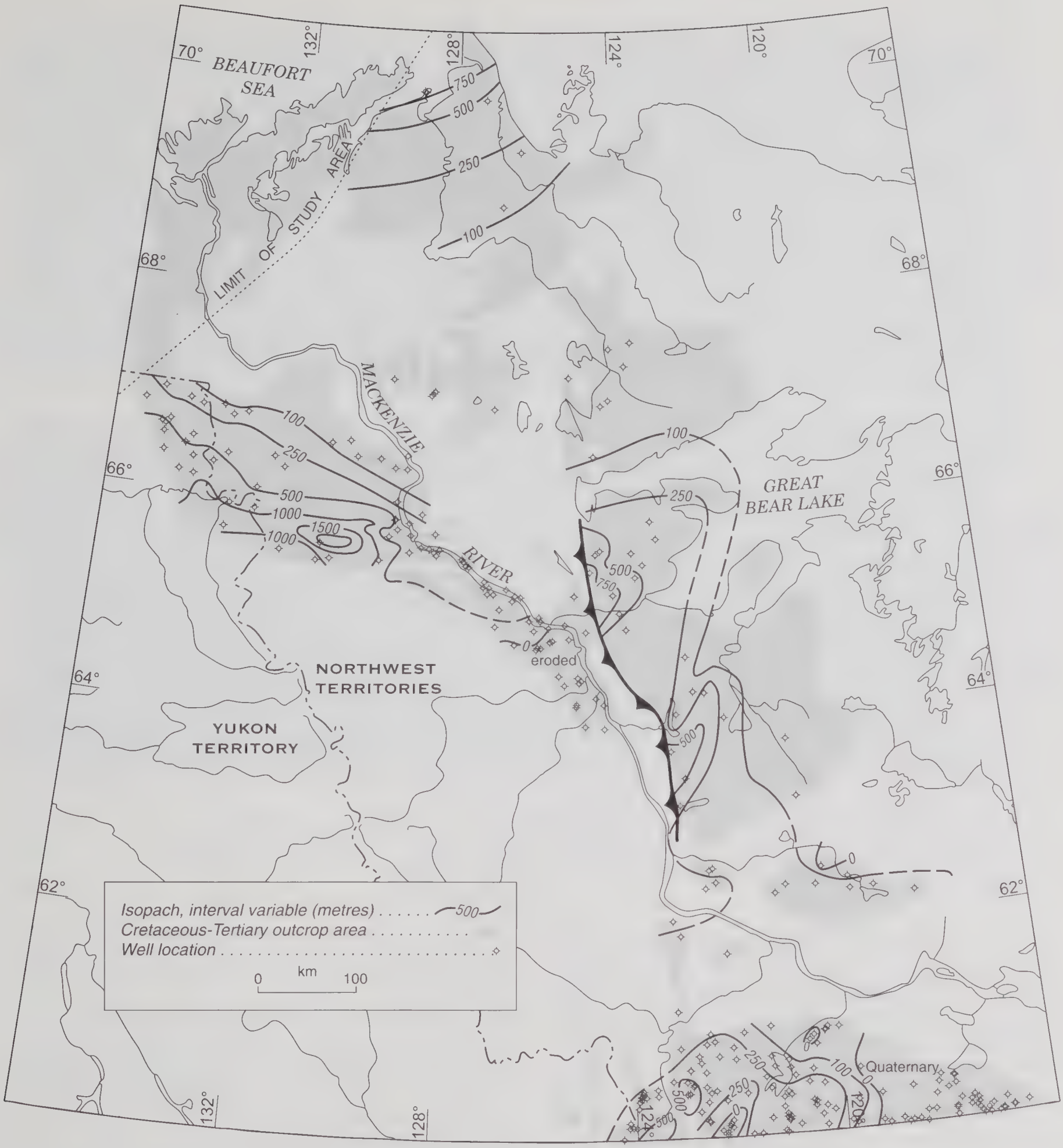

Figure 27. *Isopach map of Albian strata (Horton River, Arctic Red, and Mahony Lake formations, and part of the Fort St. John Group).*

In the Arctic Red F-47 well there are distinct intervals within the Arctic Red Formation, based on the gamma-ray and sonic log responses. These reflect variations in the silt and sand content of the Arctic Red shales and can be correlated with prominent reflections in a seismic line that intersects the well (Fig. 28). These reflections are correlatable on seismic lines throughout southeast Peel Plateau but a lack of good quality, publically available seismic lines linking the eastern and western Peel Plateau makes it difficult to extend the correlations.

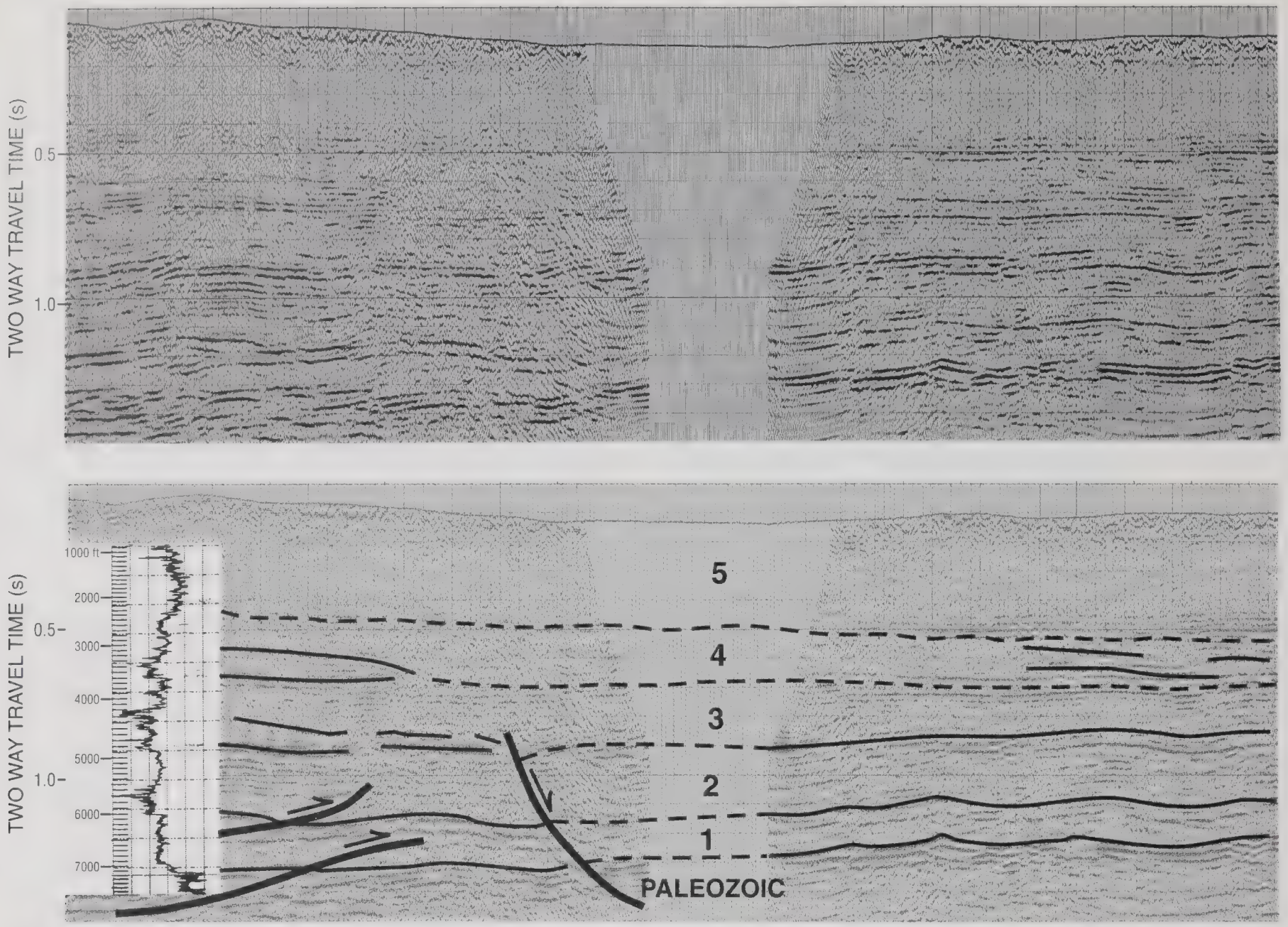

Figure 28. *Reflection seismic profile intersecting the Arctic Red F-47 well, Peel Plateau. Five seismo–stratigraphic units (numbered 1 to 5) are recognized in the Upper Aptian to Albian succession and can be correlated to sonic log-markers in the F-47 well. Units 1 to 4 correspond to the Arctic Red Formation and unit 5 to the Trevor Formation.*

Four litho–seismic units within the Arctic Red Formation of the F-47 well are recognized (Fig. 28). The first three have similar characteristics: a lower, reflection-poor interval and an upper interval with more continuous and stronger reflections. The contact between each unit is marked by a very stong, near-continuous reflection. These seismic characteristics appear to reflect the lithogical succession. The lower beds contain more clay-shale and the upper beds become increasingly more silty and sandy. The abrupt contact and density contrast between the silty to sandy shale and the overlying clay-shale gives a strong velocity contrast, hence the strong reflection at these horizons. Units 1 and 2 appear to maintain a uniform thickness when traced northward on the seismic line. Unit 3 thins northward and forms a wedge-shaped unit between units 2 and 4. Within unit 3 there are local traces of very low angle, clinoform reflections. Unit 4 also thins northward but not as rapidly as unit 3. It contains prominent clinoform reflections. Unit 4 is immediately overlain by the sandstone-dominant Trevor Formation and the reflection patterns indicate that the Trevor Formation represents the topset beds of the underlying clinoforms.

The five litho–seismic units that constitute the Arctic Red and Trevor formations represent four phases of progradation. Units 1 to 3 contain mostly bottomset beds, although there are a few very low-angle foresets preserved at the southernmost end of unit 3 (Fig. 28). Units 4 and 5 represent a complete progradational succession of bottomset, foreset and topset beds. Each of the prominent reflections separating the litho-seismic units is interpreted as a downlap and/or flooding surface.

In the vicinity of Sans Sault Rapids and extending a short distance to the west and southwest is a local succession of interbedded shale and sandstone low in the Arctic Red Formation. This interval is named the Sans Sault Member and originally was the upper part of the former Sans Sault

Figure 28. *Continued.*

Formation. The sandy interval could represent the upper part of litho-seismic division 1 seen in the F-47 well.

Foraminifers and a sparse ammonite assemblage indicate an Early to Late Albian age (Mountjoy and Chamney, 1969; Yorath et al., 1975; Yorath and Cook 1981; Aitken et al., 1982) for the Arctic Red Formation.

The presence of marine faunas, prograding clinoforms, and predominance of shale indicates a relatively low-energy, marine shelf setting. The regional setting (see later discussion of paleogeography; Dixon, 1986, 1992) indicates that the Arctic Red Formation of Peel Platau and Plain was in a foredeep and in close proximity to the source terrain. This setting suggests the clinoforms in the Arctic Red succession may have been produced by delta progradation, rather than as continental slope clinoforms.

Trevor Formation

The Upper Albian to Upper Cretaceous Trevor Formation was named and described from the Trevor Range, along the southwest margin of Peel Plateau, by Mountjoy and Chamney (1969). It extends eastward along the southern edge of Peel Plateau as far as Hume River (Yorath and Cook, 1981). Yorath and Cook (1981) identified Trevor strata in Mackenzie Plain, south of Norman Wells, but recent subsurface correlations do not support their interpretation of Trevor strata being present this far east (Dixon, 1994).

Trevor strata consist of fine to coarse grained, locally conglomeratic sandstone interbedded with shale. The Trevor Formation gradationally overlies Arctic Red strata and it is probable that the base of the formation rises stratigraphically from south to north.

Only the Arctic Red F-47 well has penetrated Trevor strata. There the succession consists a series of coarsening-upward cycles (Fig. 6). In the type area there are about 360 m of Trevor strata (Mountjoy and Chamney, 1969), increasing eastward to 602 m in the Arctic Red F-47 well, and up to 1152 m in the vicinity of Hume River (Yorath and Cook, 1981).

The age of the Trevor Formation is poorly constrained but the available data indicate a Late Albian to Late Cretaceous age, possibly as young as Turonian (Yorath and Cook, 1981; Aitken et al., 1982). Throughout northern Canada, and extending into western Canada, there is a major unconformity between Albian and Cenomanian beds (Dixon, 1993a; Leckie et al., 1992); whereas the Trevor Formation has been interpreted as representing a continuum of deposition from the Albian to Turonian (Yorath and Cook, 1981; Aitken et al., 1982). It seems highly unlikely that an event of such magnitude and extent would have bypassed the Peel Plateau area. In a section measured by Yorath (in Yorath and Cook, 1981, appendix 1, p. 53–55, section YB-69–081, units 24–30), along a tributary of Hume River, is a prominent, thick, shale-rich interval within the Trevor Formation, underlain and overlain by interbedded sandstone and shale. This shale-on-sandstone interval within the Trevor Formation suggests the presence of a major transgressive event, which could be a reflection of the Albian–Cenomanian discontinuity. To-date no paleontological data are available to verify this hypothesis although the lithological descriptions (Yorath and Cook, 1981) are similar to known Cenomanian–Turonian shales throughout the north (i.e., organic-rich, highly fissile shale). Mountjoy and Chamney (1969) described and mapped an unnamed shale above the Trevor Formation in southwest Peel Plateau which they speculated was Late Albian or younger in age. This shale could be equivalent to the shale interval described by Yorath and Cook (1981).

Detailed sedimentological analyses of the Trevor Formation are lacking because of inadequate data. However, the regional context can tell us the general depositional setting. Seismic data show that Trevor strata form topset beds above a series of prograding clinoform beds of the shale-dominant Arctic Red Formation. This fact, and the presence of coarsening-upward cycles within the Trevor Formation, point to an origin as a series of shoreface or delta-front cycles.

Mackenzie Plain

Mackenzie Plain follows the middle reaches of Mackenzie River, from about Sans Sault Rapids in the north, southward to the Liard Plateau (Fig. 1). It is bounded on its western side by the Mackenzie Mountains, and on the east by the Franklin Mountains. Within this area are found a number of small communities and the only producing oil field in the Northwest Territories, at Norman Wells. Cretaceous–Tertiary strata occupy much of the valley from Sans Sault Rapids as far south as Redstone River, south of which, lower Paleozoic rocks extend across the lowland.

In previous publications, all of the Upper Aptian to Albian succession was included in the Arctic Red Formation (Yorath and Cook, 1981; Williams, 1989; Dixon, 1994), even though a distinct basal sandy interval was recognized. It is herein proposed that the basal sandy beds be correlated with the Martin House Formation and the overlying Albian shale to the Arctic Red Formation. This proposed nomenclatural change is consistent with the stratigraphy of the Peel Plateau area (Mountjoy and Chamney, 1969).

Martin House Formation

The base of the Upper Aptian–Lower Albian succession rests unconformably on Paleozoic rocks and the lowermost beds are typically interbedded sandstone, siltstone, and shale. This sandy interval is correlated with the Martin House Formation. In the Dodo Canyon K-03 well, Martin House strata occur between log depths 2512 and 2987 ft. (765.7–910.4 m) (Fig. 8). Because of the distinct lithology and log character response these strata can be readily correlated in the subsurface. The presence of glauconite, ironstone, and the brownish coloration are typical characteristics of basal beds of the Upper Aptian to Lower Albian succession present throughout Peel Plain and Plateau.

The thickest known Martin House succession is in the Mirror O-33 well, where 173 m of strata are present. The limited thickness data suggest a lobate distribution of the Martin House succession (Fig. 26) but generally thinning to the north and northeast. The southeastern zero-edge is a truncation edge below the sub-Slater River unconformity.

Three cores were cut in the Martin House Formation, all in the Loon Creek #1 well. Thinly interbedded sandstone and shale comprise the general lithology in all cores. Sandstone beds range from 0.5 to 60 cm in thickness, but most are < 2 cm thick. Very fine crosslaminae are the most common sedimentary structures in the sandstone beds, with some beds containing burrows. Most beds have an abrupt base and the upper laminae rapidly grade into the overlying shale. Shale interbeds are generally < 4 cm thick and some contain sand-filled burrows. The lithological character of Martin House strata in these cores suggests a low-energy, marine, depositional environment.

The age of Martin House strata in Mackenzie Plain is presumed to be similar to the dated succession on Peel Plateau (Late Aptian to Early Albian).

Arctic Red Formation

Southeast of Sans Sault Rapids the bulk of the Albian interval is represented by shale of the Arctic Red Formation, which is laterally equivalent to the same strata in Peel Plateau and Plain.

The subsurface character of the Arctic Red Formation is illustrated on Figure 8, in the Dodo Canyon K-03 well. Unlike Yorath and Cook (1981, fig. 4), no Trevor Formation (typically consisting of interbedded sandstone and shale) is recognized between log depths 269 and 1509 ft. (82–460 m); the log character and lithology do not indicate the presence of significant quantities of sandstone to warrant identifying this interval as Trevor Formation. Yorath and Cook also mapped the Trevor Formation passing laterally into the Slater River Formation in the general area of the Dodo Canyon K-03 well (1981, fig. 3 and Map 1498A). The revised Cretaceous stratigraphic correlations and the reinterpreted stratigraphy of the Dodo Canyon well indicates that the Trevor Formation does not exist in this particular area and is restricted to the Peel Plateau (see Dixon, 1994).

The Arctic Red Formation abruptly overlies the Martin House Formation and the lowermost beds are characterized by a brownish grey colour, abundant ironstone and the presence of *Inoceramus* prisms (log depths 2020-2512 ft.; 615.7–765.7 m in the Dodo Canyon K-03 well). The gamma-ray response for this interval is slightly higher than that of the overlying shale interval. Abruptly overlying the brown shale is a succession of silty shale with very thin interbeds of siltstone and very fine to fine grained sandstone. At the Dodo Canyon K-03 well the Arctic Red Formation is abruptly overlain by a slightly radioactive shale of the Slater River Formation.

The subsurface lithological divisions of the Arctic Red Formation are similar to those seen in outcrop on Peel Plateau: a concretionary shale succeeded by a silty shale (Mountjoy and Chamney, 1969; Yorath et al., 1981; Aitken et al., 1982).

Within Mackenzie Plain, the Dodo Canyon K-03 contains the thickest known section of Albian strata (604.2 m). Albian strata thin southeastward and the last known occurrence in Mackenzie Plain is in Bluefish K-71 (Fig. 27). The absence of Albian beds southeast of Bluefish K-71 is due principally to sub-Slater River erosion along the Keele Arch. Albian strata reappear in Great Bear Plain.

The age of the Arctic Red Formation in Mackenzie Plain is presumed to be Albian based on comparison with the better dated sections on Peel Plateau, and the fact that it underlies the dated ?Cenomanian–Turonian Slater River Formation.

A similar depositional setting to that interpreted for Arctic Red strata on Peel Plateau and Plain is inferred, based on the similar paleogeogaphic setting and lithological succession; that is, a low-energy, marine shelf.

Slater River Formation

The ?late Cenomanian–Turonian Slater River Formation was first named by Stewart (1945), based on work by Canol Project geologists. A poorly exposed section along Slater River was proposed as a type area (Tassonyi, 1969), although no formal type section has been proposed. Because of the lack of good outcrop it is herein proposed that the Slater River Formation in the East Mackay B-45 well, between log depths 3175 and 3978 ft. (967.7–1215.2 m), be designated a reference section.

Slater River strata rest unconformably upon older beds: Albian in the western part of the Mackenzie Plain and Paleozoic rocks in the central plain (Fig. 8, 9). It is gradationally succeeded by sandstone of the Little Bear Formation (Fig. 8, 9).

In outcrop the Slater River Formation consists of soft, black shale, thin bentonite interbeds, and concretions. Selenite crystals are a common surface-weathering product. Prisms of *Inoceramus* are present in the middle part of the formation and poorly preserved fish scales are scattered throughout (Yorath and Cook, 1981).

In wells drilled to the south of Fort Norman, in the vicinity of Tertiary Hills, the Slater River Formation rests unconformably on Paleozoic rocks (Fig. 8, 9). There, the Slater River succession consists of a thin, basal sandy and silty interval, herein informally designated the Basal member, abruptly overlain by an interval of radioactive shale. This radioactive shale is a critical log marker, which facilitates reliable correlation of the Slater River Formation between wells and is especially critical for correlation into the western wells to reveal the unconformable relationship with the Albian Arctic Red Formation. Also, it reveals the true relations between the well developed basal Cretaceous sandstones in the Old Fort Point E-30 and Police Island L-66 wells and the Slater River Formation (Fig. 8, 9). Similar coarse grained to conglomeratic sandstones occur in outcrops along the trend of Keele Arch and these are believed to be equivalent to the Basal member of the Slater River Formation (Yorath and Cook, 1981). These basal sandstones become siltier and shalier westward, away from the Keele Arch. Eastward, into Great Bear Plain, the character of the basal sandstone is poorly known.

Williams (1989, fig. 27) indicated that a sandstone in the Old Fort Point E-30 well between log depths 1985–2144 ft.

is a thrust repeat of the basal Cretaceous sandstone found higher in the E-30 succession (i.e., the Basal member of the Slater River Formation). This sandstone is within a Paleozoic carbonate succession and, apparently, such a sandstone is unknown within the nearby lower Paleozoic succession; hence Williams' suggestion of a fault repeat. However, the sandstone is different from the Basal member of the Slater River Formation found higher in the well. The deeper sandstone is finer grained and contains less grey chert, giving it a lighter colour than the known Cretaceous sandstone. Also, it has a higher velocity, and it appears to be interbedded with limestone in its uppermost occurrence. These features, plus the stratigraphic–structural setting, lead me to believe the lower sandstone in the E-30 well is a Paleozoic unit, as was also interpreted by Pugh (1993, fig. 23). However, I believe Pugh's Paleozoic stratigraphy is also suspect and the sandstone may be a transgressive unit above a major unconformity. The succession above the possible unconformity may be Devonian, and that underlying the unconformity may be Cambrian to possibly Ordovician, limestone and redbeds (D. Cook and B. MacLean, pers. comm., 1996). If correctly interpreted there are some important implications for the distribution of facies types in the Cambro–Ordovician succession.

Slater River strata have been cored in the Bluefish 1A A-37, Redstone #1 J-42, Brackett Lake C-21, and Old Fort Point E-30 wells. Core from the first two wells are from the shale part of the succession and in the latter two from the Basal member. Three cores were cut in the Bluefish A-37 well and they consist of extremely fissile, light grey shale. In core 3, there are several bentonitic shales that have a "lumpy" to rubbly character and have white flecks on the rock surface. In the Redstone J-42 well the core consists of shale interlaminated with mm-thick laminae to very thin beds of siltstone and very fine grained sandstone. Carbonaceous debris is a common component and is commonly seen on parting planes. There are a few short vertical burrows.

The sandstone in the core from Brackett Lake C-21 is very friable and fine grained. A white bentonitic sandstone is present in the top 20 to 25 cm. The remainder of the sandstone is brown, possibly due to oil staining. At Old Fort Point E-30 the Basal member consists of interbedded fine to medium grained sandstone and granulestone. The granulestone is a 65 to 70 cm thick unit resting erosionally on an underlying fine grained sandstone and is overlain by fine to medium grained sandstone. Sedimentary structures are poorly defined; there are some faint crosslaminae in the fine grained sandstones and crudely defined bedding in the granulestone. The lack of sedimentary features in these cored sandstones is not conducive to an exacting interpretation of their depositional environments. Compared to the general character of the Basal member from other localities, the cored examples suggest a more energetic environment of deposition than elsewhere.

The thickest known section of Slater River Formation is in the Blueberry Creek K-53 well, where 853 m of strata are present. The next closest well is Little Bear I-70, which has only 387.1 m of Slater River strata. Most wells in the vicinity of Blueberry Creek K-53 contain less than half that well's thickness of Slater River strata, strongly suggesting that there is a repeated section in K-53. This is further supported by the fact that a thrust fault lies just to the south of the K-53 location (Yorath and Cook, 1981). If K-53 contains a repeated section, then the thickest complete section occurs in the Fort Norman K-14 well where there are 412.7 m of Slater River strata. In general, the thickest Slater River Formation occurs close to the Mackenzie Mountains (Fig. 29). There appears to be significant pre-Maastrichtian erosion on the Keele Arch, apparently extending as deep as the Slater River Formation in places (e.g., Police Island L-66, Windy River A-53).

Samples from a core in the Bluefish 1A A-37 well yielded Turonian dinoflagellates and palynomorphs low in the formation (D. McIntyre, unpublished data). Correlative strata of the Boundary Creek Formation in the northern Yukon (Dixon et al., 1992), are Cenomanian (most likely late Cenomanian) to Turonian, and it is possible that the Slater River Formation has a similar age span.

Based on the presence of marine fossils and the predominance of shale, Slater River deposition is interpreted as having been on a low-energy, marine shelf setting. The organic-rich basal beds indicate low-oxygen conditions during the early stages of deposition.

Little Bear Formation

Gradationally overlying the shale-dominant Slater River succession is interbedded sandstone and shale of the Little Bear Formation (Yorath and Cook, 1981). In its subsurface occurrence, Little Bear strata can be divided into two informal members: a Lower member, consisting of a series of coarsening-upward, shale-to-sandstone cycles in which the sandstone part of each cycle is moderately well developed; and an Upper member, in which the sandstone beds of coarsening-upward cycles are thicker and better developed than those of the Lower member. In outcrop, coal beds have been recorded from strata equivalent to the Upper member (Sweet et al., 1989). Many of the cycles can be correlated with confidence between most wells (see Fig. 3, 4 in Dixon, 1994). The contact between the lower and upper members is well defined on gamma-ray logs and can be readily correlated between wells. The coarsening-upward units in both members represent transgressive–regressive

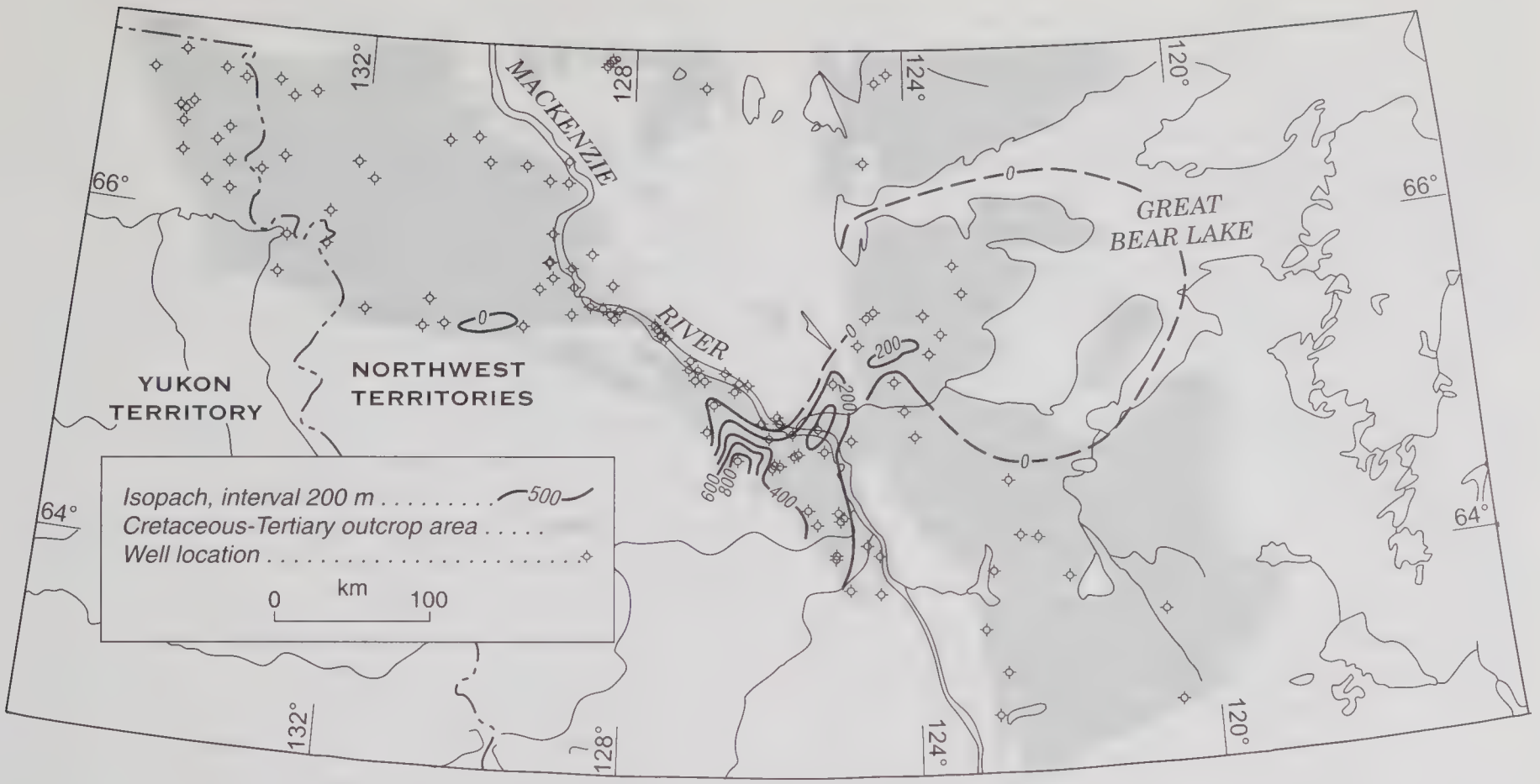

Figure 29. *Isopach map of the Slater River and equivalent formations.*

cycles of sedimentation. Coal beds in the Upper member indicate that nonmarine or brackish-water sediments are present in some of the cycles.

Complete successions of Little Bear strata range from about 285 m (Keele River L-04) to 383 m (East Mackay I-55; Fig. 30) thick. These thicknesses are much greater than that of the Little Bear from the composite type section (Yorath and Cook, 1981), which is about 230 m. Some of the difference can be accounted for by the lack of a basal and top contact in the type section and possibly incomplete measurements between the two sections that comprise the composite type section. An anomalously thick succession of interbedded sandstone and shale overlies the 'normal' Upper member in the Little Bear I-70 well (between log depths 2782 and 3285 ft.; 848–1001.3 m; Fig. 9) and also in the nearby Little Bear L-21 well. The most likely explanation is that the uppermost beds are a repeat of the upper member as a result of thrust faulting. However, it is difficult to exactly match the log character with the underlying "normal" succession of the Upper member. Alternatively, the uppermost beds within the Little Bear Formation of the I-70 could well be a previously unknown stratigraphic interval. The fact that the anomalous section is present only in the Little Bear I-70 and nearby Little Bear L-21 wells, and that all other wells penetrating the Little Bear Formation are "normal", favours the structural repetition interpretation.

Anomalously thin intervals of strata assigned to the Little Bear Formation occur in the Police Island L-66 (30.5 m) and Windy River A-53 (53 m) wells. The regional setting (Fig. 8, 9) does not favour a structurally truncated section in these wells – rather they appear to be true stratigraphic relations. This interpretation is consistent with the location of the wells on the Keele Arch, an area known to have undergone intermittent uplift and erosion. If correctly interpreted, the sandstone assigned to the Little Bear Formation in the two wells probably represents a basal transgressive sandstone

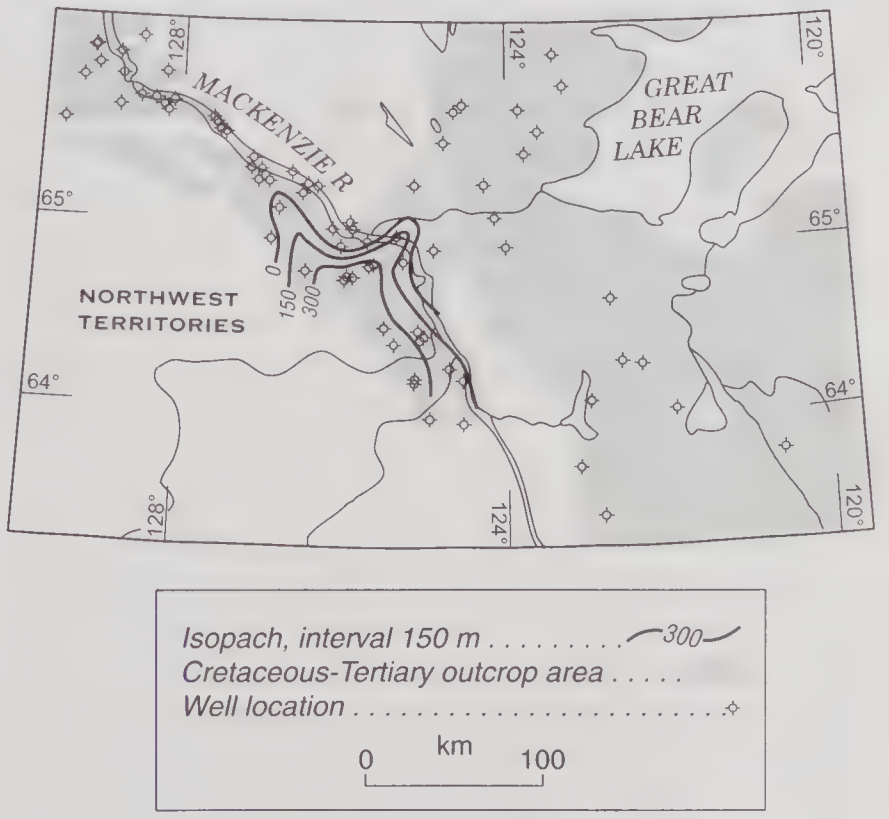

Figure 30. *Isopach map of the Little Bear Formation.*

that developed below East Fork marine shale and above a locally well developed unconformity.

Paleontological data suggest that the age of the Little Bear Formation extends from the Santonian to Campanian (Yorath and Cook, 1981; Sweet et al., 1989). However, the gradational contact with the underlyng Slater River Formation suggests that some strata may be as old as Turonian. If lower Little Bear strata are as old as Turonian then regional considerations indicate the possibility of an intra-Little Bear unconformity, such as is present at the base of the Smoking Hills Formation in Anderson and Horton plains. The boundary between the Lower and Upper members is very abrupt and could indicate a discontinuity. However, as yet, there are no paleontological data to support this inference.

The general depositional setting is interpreted as a series of prograding shoreface or delta-front deposits, possibly with more nonmarine beds in the Upper member.

East Fork Formation

An abrupt shale-on-sandstone contact marks the boundary between the Little Bear and East Fork formations (Fig. 8, 9). This is a fundamental stratigraphic break, herein interpreted as a maximum flooding surface. This concept differs drastically from the character of the contact as described by Yorath and Cook (1981) and Sweet et al. (1989), who indicated a transitional facies boundary. However, Yorath and Cook (1981, p. 31) did suggest that at the type section of the Little Bear Formation the contact possibly was disconformable. This contact is a very prominent log character change and can be readily correlated between wells. If the Little Bear–East Fork contact is a maximum flooding surface then the underlying sandstone of the Little Bear Formation is probably a marine transgressive unit resting on an unconformity or transgressive surface. There appears to be a locally developed pre-East Fork erosional unconformity on the Keele Arch, overlain by a thin sandstone succession interpreted as a transgressive interval. The log character of this transgressive sandstone in the Police Island L-66 and Windy River A-53 wells is remarkably similar to the uppermost sandstones of the Little Bear Formation in wells to the south and west.

The East Fork Formation is a shale and siltstone unit overlain by interbedded sandstone, conglomerate, shale, and coal of the Summit Creek Formation. In virtually all of the wells penetrating the East Fork Formation the lowermost 100 m of strata is a shale-rich succession (Fig. 8, 9) overlain by a thin siltstone or sandstone succession. Overlying the silty or sandy unit is a thick succession of shale, the gamma-ray log signature of which is slightly more ragged than the basal shale, suggesting the common presence of thin siltstone and sandstone beds.

Yorath and Cook (1981) included an interval of interbedded sandstone and shale that gradationally overlies East Fork shales as the Sandstone member of the East Fork Formation. Sweet et al. (1989) preferred to include these beds in the Summit Creek Formation. While Sweet et al.'s (1989) proposal is lithostratigraphically acceptable it must be recognized that the lithostratigraphic base of the Summit Creek Formation in some northern occurrences is an unconformity but in the south it is stratigraphically lower and a facies contact (sensu Sweet et al., 1989). Strata that could be correlated to Yorath and Cook's (1981) Sandstone member are present principally in the wells of the Tertiary Hills; for example, Keele South A-28, Tate J-65. The log character in these wells indicates that these beds consist of a series of shale-to-sandstone, coarsening-upward cycles.

The thickest development of East Fork strata occurs close to the Mackenzie Mountains, and thins to the northeast (Fig. 31). A possibly tectonically thickened succession is present in Little Bear I-70, where 809 m of strata are present, whereas in the nearby Little Bear L-21 well only 584 m are present. Pre-Summit Creek erosion of East Fork shale is apparent on the Keele Arch, especially in the Old Fort Point E-30 well (Fig. 9)

East Fork strata are late Campanian to early Maastrichtian in age (Yorath and Cook, 1981; Sweet et al., 1989), and are interpreted as low-energy, marine shelf deposits that grade upward into the shoreface to delta-front deposits of the lower Summit Creek Formation.

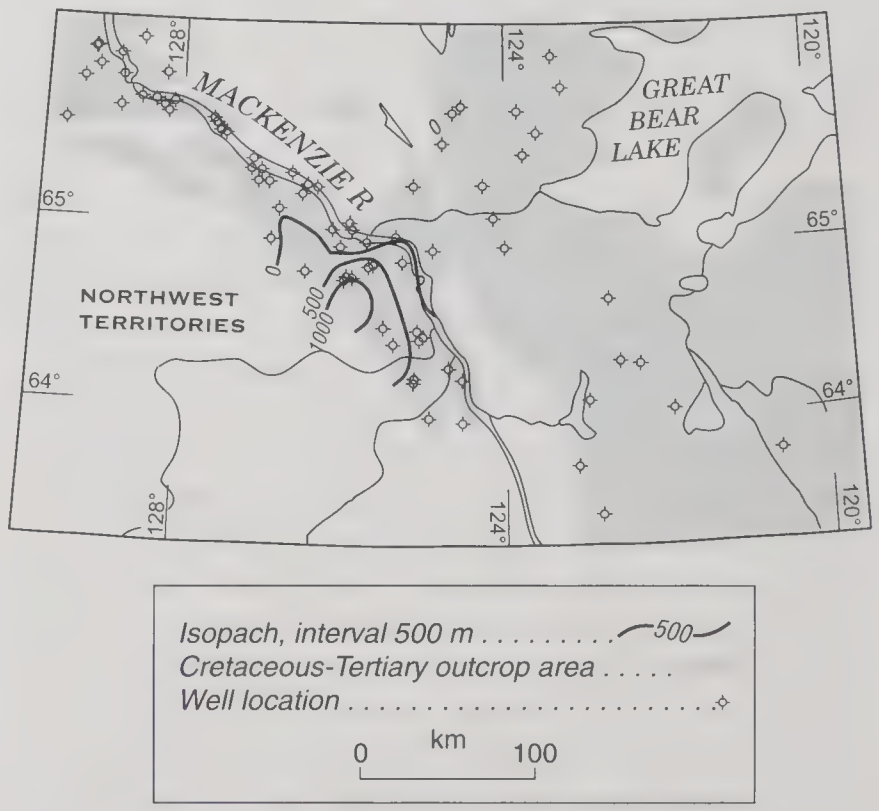

Figure 31. *Isopach map of the East Fork Formation.*

Summit Creek Formation

Summit Creek Formation (Yorath and Cook, 1981) is a succession of interbedded sandstone, conglomerate, shale, and coal of middle Maastrichtian to Paleocene age (Sweet et al., 1989). The formation is restricted to the Brackett Basin, centred around Tertiary Hills and the Fort Norman area. Summit Creek strata are very poorly represented in the wells drilled in Brackett Basin, largely because the upper levels of the exploratory holes are generally behind casing. Most comprehensive descriptions of Summit Creek strata are based on outcrop studies (Yorath and Cook, 1981; Sweet et al., 1989).

As indicated elsewhere, Sweet et al. (1989) included Yorath and Cook's (1981) Sandstone member of the East Fork Formation into the Summit Creek Formation, a practice followed in this report. The base of the Summit Creek Formation in the wells is chosen at the first occurrence of significant sandstone above which coarse grained siliciclastic sediments are a major component of the formation. In the southern part of Tertiary Hills the lowest beds consist of a series of coasening-upward cycles succeeded by interbedded conglomerate, sandstone and coal.

In outcrops, the first significant conglomerates and coal-bearing beds occur in strata of the *Porosipollis porosus* Zone (Sweet et al., 1989, fig. 5). Such beds are middle or late Maastrichtian in age. The level at which conglomerates become common is herein interpreted as a regional unconformity. The presence of such an unconformity is consistent with the known occurrence of a major unconformity between late Maastrichtian and older beds in the northern Yukon (Dixon, 1993a; i.e., between the Tent Island and Boundary Creek formations). Sweet (1978) used the common occurrence of *Aquilapollenites conatus* and *Wodehousia* spp. in the basal Tent Island Formation to indicate a Maastrichtian age. *Aquilapollenites conatus* is a common component of the *Porosipollis porosus* Zone of the Summit Creek Formation of Mackenzie Plain (Sweet, 1978; Sweet et al., 1989), suggesting possible correlation of the basal Tent Island and upper Summit Creek strata.

Summit Creek strata commonly contain coarsening-upward cycles of probable delta-front origin in the lower beds, overlain by fining-upward cycles of fluvial channel and floodplain origin (Sweet at al., 1989).

Great Bear Plain

Great Bear Plain extends eastward from the Franklin Mountains to Great Bear Lake, and from Colville Hills in the north to Great Slave Plain in the south (Fig. 1). Although Horn Plateau is incorporated in the Great Slave Plain physiographic province, its Cretaceous geology is more similar to that of Great Bear Basin; consequently it will be discussed in the section dealing with Great Bear Plain. This differs from past practice, where the Horn Plateau Cretaceous has been identified as the Fort St. John Group (Williams, 1977a), present south of Mackenzie River in Great Slave Plain. The headwaters of Horton and Kugaluk rivers flow through the northern Great Bear Plains, on their way to Horton Plain. It is an area of rolling, tree-covered hills and is part of the taiga biogeographic zone.

In the past, Upper Aptian to Upper Cretaceous strata within Great Bear Plain have not been divided into formal formations. The bulk of the Mesozoic succession in Great Bear Plain is similar to the Albian of the Mackenzie Plain and Peel Plateau. The main difference is the thinner character of the succession in Great Bear Plain. Williams (1989) also noted the similarities but because of the physical separation of the areas by the Keele Arch he preferred not to use the same stratigraphic nomenclature.

The Upper Aptian to Albian succession was informally divided into five units, A to E, by Yorath and Cook (1981, fig. 4) and Williams (1989). However, some problems identifying and correlating these informal units throughout the basin are apparent and a reassessment of the internal stratigraphy is warranted. It is proposed that the use of Martin House and Arctic Red formations be extended into the Albian of Great Bear Plain and Horn Plateau, and a new name be introduced for the Albian sandstone and shale succession (the Mahony Lake Formation) above the Arctic Red shale.

Upper Cretaceous strata have been tentatively identified in the subsurface (Yorath and Cook, 1981; Williams, 1989) and scattered outcrops are present between the South and Smith arms of Great Bear Lake (Yorath and Cook, 1981; McIntyre, pers. comm., 1994). However, because there is a poor understanding of the distribution, age, and lithology of the Upper Cretaceous, no formal terminology is proposed.

The thickest penetrated Cretaceous succession occurs between Great Bear River and Smith Arm of Great Bear Lake (Fig. 4), where up to 1000 m of section may be present. The bulk of these strata is Albian. Another locally thick occurrence is present to the south, in the vicinity of the Fish Lake G-60 well, where between 500 and 600 m of Cretaceous strata are preserved. Seismic data (B. MacLean and D. Cook, pers. comm., 1996) from the area just north-northwest of Blackwater Lake indicate that the Cretaceous to Quaternary succession is more than 1000 m thick, possibly as much as 1300 m just east of the McConnell Range of the Franklin Mountains. Strata thin to the east, away from the Franklin Mountains. The thinning trend is in part depositional as well as preservational.

Martin House Formation

The Martin House Formation consists of interbedded sandstone, siltstone, and shale at the base of the Upper Aptian to Albian succession of Great Bear Plain and is equivalent to Yorath and Cook's (1981) Units A and B. Glauconite, ironstone and carbonate material are common and a brownish grey colour is typical. In some wells the lowermost beds of the Martin House Formation consist of a distinct "clean" sandstone immediately overlying the basal unconformity (unit A of Yorath and Cook, 1981). The contact between the lowermost "clean" sandstone and the overlying beds is commonly abrupt. The area of occurrence of this "clean" sandstone is limited to the Lost Hills Lake area, between Smith and Keith arms of Great Bear Lake.

The White M-04 well is designated a reference section for the Martin House Formation in the Great Bear Plain area (Fig. 32). Martin House strata occur between log depths 1088–1464 ft. (331.6–446.2 m) and consist of a "clean" basal sandstone between 1405–1464 ft. (428.2–446.2 m), overlain by interbedded sandstone, siltstone and shale. A core (1445–1500 ft.; 440.4–457.2 m) that intersects the contact with Paleozoic carbonate includes about 7.3 m of the basal Martin House Formation. The basal Martin House strata consist of crossbedded, medium to coarse grained sandstone and pebbly sandstone. In the White M-04 well, Martin House strata are abruptly overlain by Arctic Red shale; as evident by the sonic and gamma-ray log responses.

South of Blackwater Lake the Martin House Formation becomes less well defined and the Upper Aptian to Lower Albian succession becomes shalier. Farther south, in the Horn Plateau, the Martin House equivalent interval is very silty and shaly but can be identified below a distinct radioactive shale (Fig. 11). Correlations of Cretaceous strata in Great Slave Plain (see later discussion) indicate that strata equivalent to the Arctic Red (Garbutt Formation of the Fort St. John Group) overlap the Martin House Formation southward, to rest directly on Paleozoic beds (Fig. 12, 13).

Several cores have been cut in the Martin House Formation of Great Bear Plain: at Great Bear River N-30, Losh Lake G-22, White M-04, Whitefish H-34, and Whitefish K-76. The character of the sandstones varies with proximity to the basal contact. Sandstones from near the base of the unit tend to be medium grained, locally pebbly to conglomeratic, and crossbedded. Those from higher levels are generally very fine to fine grained, finely laminated, commonly burrowed, and are interbedded with shale. In the Great Bear N-30 core, bivalve shells are present in several sandstone beds. In White M-04 and Whitefish H-34, the contact between Paleozoic and Mesozoic strata was cored. The Paleozoic carbonates are either brecciated or highly fractured and are abruptly overlain by siliciclastics. In Whitefish H-34 the basal 0.3 m of the Mesozoic consists of

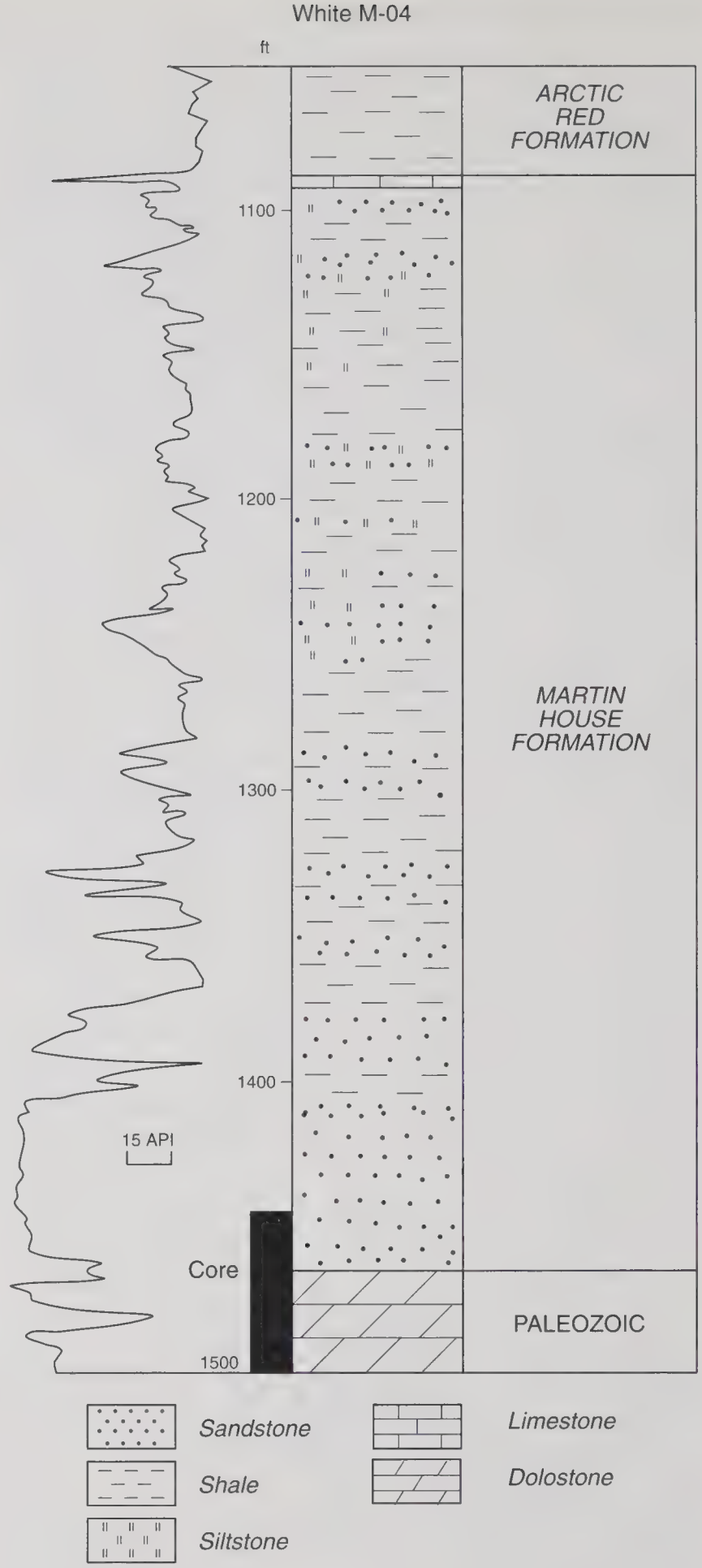

Figure 32. *Gamma-ray log response and lithology of the Martin House Formation in the White M-04 well.*

a black shale containing thin laminae and interbeds of sandstone, abruptly overlain by a medium grained sandstone that contains shale clasts in its basal few centimetres.

The thickest occurrence of Martin House Formation is found between the Smith and Keith arms of Great Bear Lake,

where up to 142 m are known in the Whitefish K-76 River well (Fig. 26). In general, Martin House strata thin towards the Franklin Mountains and thicken eastward. Because of the lack of data in the eastern area of Great Bear Plain the extent of eastward thickening is not known, although there are small indications that strata may begin to thin east of the Losh Lake G-22 well (Fig. 26). These trends suggest the presence of a minor depocentre in the Great Bear Plain (Great Bear Basin), separated from the Mackenzie Plain area by a relatively positive area (probably an Albian expression of the Keele Arch).

The available lithological data indicate a marine origin for the Martin House Formation, which is consistent with its position as a transgressive sandstone.

The age of the Martin House Formation in Great Bear Plain has not been determined from indigenous fossils but it occurs below dated Lower Albian beds (St. Charles Creek H-61 well). Its comparable stratigraphic position to better dated Martin House Formation of Peel Plateau suggests an age of Late Aptian to Early Albian.

Arctic Red Formation

The Martin House Formation is abruptly overlain by shale of the Arctic Red Formation (equivalent to units C and D of Yorath and Cook, 1981). In the wells on Horn Plateau and the Cretaceous outlier around the Ebbut J-05 well, the shale immediately overlying the Martin House Formation has a high gamma-ray response (Fig. 11). Arctic Red shales commonly are brownish grey in colour and calcite prisms from *Inoceramus* are a common component. In many wells, especially in the southern part of the area, the formation contains a thin radioactive shale zone low in the Arctic Red succession (e.g., Wolverine D-61, Grey Goose N-70, Russell M-07 and Great Bear River N-30; Ochre River I-15; Davidson Creek P-02,: Harris River F-71: Fig. 9, 10, 11) that can be traced throughout most of the basin. There are a number of other wells where the radioactive shale has not been identified because of inadequate geophysical logs. The radioactive shale may be correlative to radioactive marker 3 of Williams (1978), in the Fort St. John Group of the Great Slave Plain area.

The Great Bear River N-30 well is selected to be a subsurface reference section for the Arctic Red Formation in Great Bear Plain (Fig. 10). Arctic Red strata occur between log depths 916–2012 ft. (279.2–2012 m) and are gradationally overlain by interbedded sandstone and shale of the Mahony Lake Formation. Sonic and gamma-ray logs indicate that the contact with the underlying Martin House Formation is abrupt. A slightly radioactive zone is present between 1445–1510 ft. (440.4–460.2 m). Immediately below the Mahony Lake Formation the Arctic Red Formation has a distinct sonic log character, which can also be identified in adjacent wells. Between log depths 1060 and 1280 ft. (323.1–390.1 m) the velocity of the Arctic Red strata is higher than those below. This interval is equivalent, in part, to Yorath and Cook's (1981) unit D. The velocity of the shale above this interval, between 916 and 1445 ft. (279.2–440.4 m), abruptly declines, and is less than the "normal" velocity of the Arctic Red shale. These changes are not always reflected in the other logs types.

Two cores from the Arctic Red Formation at St. Charles Creek H-61 consist of predominantly dark grey to black shale, with some zones of secondary carbonate development. Early Albian foraminifers were recovered from these two cores (D.H. McNeil, pers. comm., 1994).

In Horn Plateau there is an isolated sandstone outcrop on the southwest flank of the plateau, first described by Whittaker (1923, p. 99) and named the Rabbitskin Sandstone. Williams (1977a, fig. 37.7) compiled a cross-section through the Horn Plateau on which he positioned the sandstone outcrop and tentatively identified it as Upper Cretaceous. The relatively low stratigraphic position of this sandstone and its projected distance above a radioactive shale that appears to correlate with radioactive marker 1 of the Great Slave Plain succession (Williams, 1978) tends to favour it being within the Arctic Red Formation.

The thickest known occurrence of the Arctic Red Formation is in the Blackwater E-11 well, where 506 m of strata are present in a local preservational lobe (Fig. 27). A second lobe occurs in the vicinity of the Mahony Lake I-74 well, where 374 m of strata are preserved (Fig. 27). The thickness trends are a function of erosion and original depositional trends.

The age of the Arctic Red Formation in Great Bear Basin has been determined to be Early to Middle Albian (Yorath and Cook, 1981).

The marine fossils and predominance of fine grained siliciclastic sediment point to a low-energy marine depositional setting, probably a marine shelf.

Mahony Lake Formation (new name)

The Mahony Lake Formation is an Albian unit that consists of a relatively thick interval of interbedded sandstone, siltstone and shale gradationally overlying the Arctic Red Formation. The vertical extent of this unit is commonly not well defined because in most wells the formation top is behind surface casing and geophysical logs are unreliable. In some wells Upper Cretaceous strata may be present in the uppermost beds (e.g., Mahony Lake I-74), further complicating the choice of an upper contact.

The Sinclair Mahony Lake I-74 well is designated the type section (Fig. 10), from which the formation name is derived. Mahony Lake strata occur between log depths 460–1660 ft. (140.2–506 m). Mahony Lake I-74 is located at 65° 23' 36"N, 124° 43' 30"W at a ground elevation of 1000 ft. (304.8 m), and with a KB of 18 ft. (5.5 m). Drilling commenced 24th March 1969 and was completed 28th April 1969. The upper contact is less well established and, based on lithological samples, occurs where bentonitic shales overlie interbedded sandstone and shale of the Mahony Lake Formation. Bentonitic shales are more typical of Upper Cretaceous strata in this area. Surface casing extends to 649 ft. (197.8 m); consequently no geophysical logs are available through the upper part of the formation. The lower contact is gradational with the underlying Arctic Red Formation and is chosen at the base of the first significant siltstone and sandstone interval (based on gamma-ray response), above which sandstone is a prominent part of the succession.

In Mahony Lake I-74 the lowest sandstone-rich interval contains at least five coarsening-upward units. These in turn are part of a larger scale coarsening-upward succession that begins in the uppermost shales of the Arctic Red Formation (Fig. 10). This lower sandy interval is abruptly overlain by shale and siltstone. The shale–siltstone interval is gradationally succeeded by another sandstone-rich succession, also consisting of medium-scale, coarsening-upward cycles. An abrupt contact with overlying shale marks the termination of the second sandy interval. The sandstones in the Mahony Lake Formation are generally very fine to fine grained with some medium grained units. No wells contain strata stratigraphically higher than those in Mahony Lake I-74, consequently the vertical changes and character of the upper part of the formation are unknown, other than the general lithology from the cuttings samples.

Other wells in which the Mahony Lake Formation occurs include Wolverine Creek D-61, Whitefish River H-34, Whitefish River K-76, Lost Hill Lake F-62, Great Bear River N-30, Grey Goose N-70, White M-04, and possibly St. Charles Creek H-61. It is obvious from the locations of these wells (Fig. 9, 10) that the Mahony Lake Formation is present only where a thick Albian succession has been preserved, between Great Bear River and the Smith Arm of Great Bear Lake.

In Great Bear Plain, Mahony Lake strata reach a maximum thickness of 356.8 m in Mahony Lake I-74, thinning to the east and south. Much of the thinning is due to truncation below either a sub-Upper Cretaceous or sub-Quaternary unconformity. However, based on regional thickening trends of the total Albian succession (Fig. 27) it is probable that the Mahony Lake Formation depositionally thickens toward the west.

The age of the Mahony Lake Formation is believed to be entirely Albian, based on regional considerations and the identification of Middle Albian foraminifers from the Wolverine Creek D-61 well, collected from log depth 420 ft. (128 m) (Geological Survey of Canada paleontological report 15Gen-TPC-1971; cited in Yorath and Cook, 1981, p. 58).

A lack of core and outcrop precludes detailed sedimentological analysis but a general setting can be interpreted based on the presence of marine fossils and the common occurrence of coarsening-upward cycles within the formation. These features suggest a series of prograding shoreface or delta-front cycles.

Upper Cretaceous

Isolated outcrops of Upper Cretaceous strata have been reported in the area between the Franklin Mountains and Great Bear Lake and tentatively identified in some of the wells in the same area (Yorath and Cook, 1981; Williams, 1989). In many of the wells, the location of these presumed Upper Cretaceous beds is in strata behind casing, therefore the cuttings samples are either widely spaced or were not collected, and there are no geophysical logs available. Published paleontological data indicate the strata represent a range of ages, from Turonian to Maastrichtian.

In Grey Goose N-70 (Fig. 9) there is an abrupt change at log depth 390 ft. (118.9 m), where well developed, porous sandstones overlie Albian beds. These sandstones are abruptly overlain by a highly fissile, possibly bituminous, shale succession. Yorath and Cook (1981) and Williams (1989, fig. 24) interpreted these beds as Upper Cretaceous, an interpretation followed in this report. Oil staining is common in the sandstones at the base of the presumed Upper Cretaceous succession (see Williams, 1989, fig. 24). Regionally, a major unconformity separates Upper Cretaceous from Lower Cretaceous strata (Dixon, 1993a), which presumably is represented in the Cretaceous of Great Bear Plain.

Shales assigned to the Upper Cretaceous in some of the wells exhibit a distinct fissile and bentonitic character, typical of Upper Cretaceous organic-rich shales in the Mackenzie Plain (i.e., Slater River Formation). These characteristics may indicate that the presumed Upper Cretaceous shales in Great Bear Basin also are organic-rich.

Only a thin cover of Upper Cretaceous strata are known in Great Bear Plain (Fig. 9, 10). The thickest known section occurs in the Mahony Lake I-74 well, where 229 m of strata have been identified tentatively as Upper Cretaceous.

The broad age range of the identified Upper Cretaceous strata indicates that there may be thin, scattered equivalents of the Slater River, Little Bear, or East Fork formations present in parts of Great Bear Basin.

The depositional setting of these isolated Upper Cretaceous strata cannot be interpreted with any confidence, although the regional paleogeographic setting (see later discussion) suggests a predomiantly marine origin.

Tertiary

Scattered outcrops of unconsolidated to weakly cemented granulestones and medium to coarse grained sandstones, commonly associated with carbonaceous to coaly shales, have been reported from Scented Grass Hills, Many Small Lakes area, and Grizzly Mountain (Yorath and Cook, 1981; Duk-Rodkin and Hughes, 1994, fig. 5). These are presumed to correlate with the Summit Creek Formation of Mackenzie Plain and are likely nonmarine in origin.

Great Slave Plain

The area south of Great Bear Plain and east of the Cordilleran mountain front, as far east as the Precambrian Shield, is part of Great Slave Plain (Fig. 1). Mackenzie River flows westward across Great Slave Plain, turning abruptly north near the mountain front. At this northerly bend the Liard River joins the Mackenzie, having flowed northward along the mountain front from Liard Plateau. North of Mackenzie River there is a low upland known as Horn Plateau (the stratigraphy of which was dealt with in the section on Great Bear Plain) and south of the river, close to the border with Alberta and British Columbia, are the Cameron Hills.

Upper Aptian to Campanian strata are present in this area, represented by the Fort St. John Group, and the Dunvegan, Kotaneelee, and Wapiti formations (Fig. 15). Only the Fort St. John Group is widespread. The other units are more localized, with the Dunvegan Formation commonly capping some of the hills northwest and south of Trout Lake. Locally thick Quaternary deposits commonly obscure the underlying bedrock geology and in the eastern Cameron Hills, the bulk of the mapped Cretaceous (Douglas, 1974) appears to be mostly a thick Quaternary succession (up to 300 m thick). There may be thin remnants of Fort St. John strata under the Quaternary of eastern Cameron Hills but the available data from the exploratory wells is generally inadequate for accurate assessments. Although many wells in this part of the Cameron Hills have had Cretaceous strata identified in the succession, the choice of Cretaceous strata (well history reports and formation tops provided by Indian and Northern Affairs, Canadian Oil and Gas Lands Administration, and the National Energy Board) is unreliable because of a lack of geophysical logs and rock samples from shallow depths. In many cases, the intervals identified as Cretaceous are either Quaternary deposits or Paleozoic shale units.

Fort St. John Group

The Fort St. John Group was originally defined in northeast British Columbia by Dawson (1881), although it was not given group status until 1943 (Wickendon and Shaw, 1943; see also Hills et al., 1981, for a review of the history of nomenclature). Equivalent, and similar looking, strata are present in the adjacent Northwest Territories and southeastern Yukon, and the stratigraphic terminology from British Columbia has been carried into these areas, both for outcrop and subsurface occurrences. The reader is referred to Stott (1982) for a comprehensive account of previous work done in the area.

Although surface mapping indicates Fort St John strata are present as far east as about 116°W in the Cameron Hills (Douglas, 1974), the data from exploratory wells suggest that much of these easternmost occurrences are thick Quaternary deposits resting directly on Paleozoic strata. It is not until west of about 119°W that Cretaceous strata are readily identified. However, thin remnants of Cretaceous shale may be present in the Cameron Hills but they are difficult to identify with the presently available well data (e.g., North Cameron Hills M-05, possibly between log depths 365–442 ft.). In the area of Celibeta Lake and the Trout River K-33 and D-66 wells, Quaternary sediments rest directly on Paleozoic rocks (Williams, 1977b, 1978).

In the type area, Fort St. John strata consist of the following formations (bottom to top): Chinkeh, Garbutt, Scatter, Lepine, Sikanni, and Sully (Stott, 1982; Leckie et al., 1991). It is a succession dominated by shale with several sandstone-rich formations and members. Only the sandy Scatter Formation has been subdivided into members: the Bulwell (sandy), Wildhorn (shaly), and Tussock (sandy) members (Stott, 1982). The formations and members have been recognized in the mountains and foothills, and the subsurface of northeast British Columbia, but are less readily identified in the subsurface of Great Slave Plain. There, the Upper Aptian to Albian succession is generally identified as undifferentiated, shale-dominant Fort St. John Group, although sandy intervals are present throughout the interval. Because of the presence of major truncation surfaces within the Fort St. John Group (Fig. 12–14) distinguishing various component formations is difficult in places, and attempting to apply the nomenclature can lead to a confused stratigraphic interpretation. Consequently, within this report the component formations are not always identified, although in some of the western wells, where a fuller succession is preserved, some of the formations can be

identified. Some exceptions will be noted, such as the recognition of the Chinkeh Formation; an easily identified, but only locally occuring, basal sandstone. Some authors have used marker beds, commonly radioactive shales, to infer correlations with the named formations (Williams, 1977a, 1978; Stott, 1982), the value of which will be discussed later.

Three prominent radioactive shale intervals are present within the Fort St. John Group (Fig. 11–14) and can be traced between subsurface Cretaceous sections in the southern part of Great Slave Plain. These radioactive shale markers were first used to correlate strata within the Fort St. John Group in northeast British Columbia and northern Alberta (Thompson, 1977). In the succession of northeast British Columbia and northern Alberta, four radioactive shale horizons were identified but only three were correlated into the succession of the Northwest Territories (Thompson, 1977, fig. 4; Williams, 1978; Stott, 1982, fig. 20).

The lowest radioactive shale marker (marker 1) occurs very close to the base of the Fort St. John Group and can be traced from the Horn Plateau into the subsurface Cretaceous sections around Trout Lake (Fig. 11–14). East and southeast of Trout Lake this marker commonly appears to rest directly on the basal unconformity, although careful examination of the logs shows a thin "normal" shale or silty to sandy bed separates it from the Paleozoic succession (Williams, 1978). Farther to the west and northwest, the radioactive shale becomes increasingly separated from the sub-Fort St. John unconformity by a silty to sandy interval (Fig. 13, 14).

The next highest radioactive shale marker (marker 3) occurs within the lower part of the Fort St. John Group in Great Slave Plain, commonly 60 to 120 m above the lowest radioactive shale marker. Radioactive shale marker 2, identified in the Fort St. John Group of British Columbia, was not correlated into the Northwest Territories succession (Thompson, 1977; Williams, 1978; Stott, 1982).

Williams (1978, fig. 2) indicated that the base of marker 3 correlated with the basal shale of the Lepine Formation where it abruptly overlies the Scatter Formation, hence the designation of marker 3 as the "Scatter marker". Stott (1982, fig. 20), on the other hand, implied it fell within the Lepine Formation. Williams' correlation seems more probable based on the regional setting, log correlations (Fig. 12, 14), and lithological succession. Radioactive shale marker 3 is best developed in the wells around Trout Lake, tending to become thinner and less radioactive to the west, apparently grading laterally into a "normal" shale on top of the Scatter sandstone.

In outcrop the Scatter Formation has been divided into three members (Stott, 1982): two sandstone units separated by a shale-dominant interval. The identification of these members in the subsurface is commonly not possible. Also, subdivision of the subsurface Scatter Formation is further complicated by the apparent eastward truncation of its upper beds (i.e., equivalents of the Wildhorn and Tussock members; Fig. 12, 14) by an intra-Scatter unconformity.

Radioactive marker 4 occurs high in the Fort St. John Group and correlations indicate it is equivalent to the Fish Scales Bed (Thompson, 1977, fig. 2). Because the Fish Scales Bed is close to the upper erosional surface of Fort St. John strata it does not extend very far east and north, and is rarely found east of 120°W (Williams, 1978, fig. 5) or north of Trout Lake. Traced westward it appears to fall within the Sully Formation (Williams, 1978; Stott, 1982, fig. 20). Fish Scales strata consist of organic-rich, commonly bentonitic, radioactive, dark grey to black, fissile shale that contains abundant fish scales.

Williams (1978, fig. 3) also identified a "Sikanni marker" – a sharp deflection of the gamma-ray and sonic log traces due to shale resting abruptly on a silty to sandy interval. This horizon occurs 150 to 250 m above the top of marker 3 (Scatter marker) in the wells of the plains area. Williams (1978) suggested marker 4 correlates with the top of the Sikanni Formation, a sandstone unit within the Fort St. John Group of Liard Basin (Stott, 1982). However, careful recorrelation of the cross-sections illustrated in Stott (1982) and Thompson (1977) clearly shows that, in northeast British Columbia, the Sikanni Formation is truncated eastward below a pre-Fish Scales unconformity (see later discussion of regional correlations). This stratigraphic geometry is also present in the southern Northwest Territories, and the Sikanni Formation has been eroded from Great Slave Plain. The correlations indicate that the "Sikanni marker" of Williams (1978) is within the lower part of the Lepine Formation and represents the top of a coarsening-upward interval, and that his suggestion that marker 4 correlates with the top of the Sikanni Formation is invalid. Because of these correlations it is suggested that the use of "Sikanni marker" be abandoned because it incorrectly implies correlation with the top, or some part, of the Sikanni Formation.

Although the Fort St. John Group is dominated by shale and siltstone throughout Great Slave Plain, thin beds of very fine to fine grained, commonly glauconitic, sandstone are present. With the exception of a locally occurring basal sandstone, most sandstone units commonly cap poorly defined (by log character) coarsening-upward cycles. The tops of these cycles are readily identified by the abrupt deflection of log traces – usually the gamma-ray and/or sonic logs. In general these silty to sandy intervals tend to become sandier toward the west, although very few areas contain well developed "clean" sandstones.

Leckie et al. (1991) identified a local basal sandstone of the Fort St. John Group (the Chinkeh Formation) from outcrops and some subsurface locations (1991, fig. 12). Williams (1978) also identified a basal sandstone in the Fort St. John Group but did not name the unit. Chinkeh sandstone occurs in the following wells: Arrowhead B-41, L-49, and N-02, Petitot C-60, Bovie M-05, and Celibeta B-25 and D-66. These occurrences define a linear, west–northwest-trending subcrop area in westernmost Great Slave Plain (Fig. 33). Wells to the northeast and southwest of this trend contain no basal sandstone, rather they contain a very thin silty to sandy shale at the base of the Fort St. John Group (Fig. 12, 13). This west–northwest-trending belt of Chinkeh sandstone appears to be oriented parallel to similar isopach thicks noted in outcrop areas to the west (Leckie et al., 1991, fig. 12). Williams' (1978, fig. 4) mapped occurrence of the Chinkeh sandstone is more irregular than presented herein, because of the presence of a possible Chinkeh-equivalent in the Bovie M-05 well (it is still uncertain if the sandstone in the Bovie M-05 well is Cretaceous or Paleozoic, although for this discussion it is assumed to be Cretaceous). However, the Bovie M-05 well is separated from the main sandstone subcrop by an area with no basal sandstone, as evident in the Celibeta D-31 well, located between Bovie M-05 and the occurrence of Chinkeh sandstone to the northwest. There is no well developed Chinkeh in the D-31 well, only a 1.5 m silty to sandy shale between radioactive marker 1 and the basal unconformity. The few wells drilled in the northern part of the Liard Basin contain no Chinkeh Formation, rather the basal Fort St. John Group consists of silty shale resting unconformably on Triassic or Paleozoic rocks (e.g., Kotaneelee B-38, Pointed Mountain P-24).

Only one core has been recovered from the Chinkeh Formation, in the Arrowhead B-41 well (Fig. 34–36). Part of the core penetrates a porous, gas-bearing sandstone (Fig. 35c, d) present in the central part of the core, from 616.3 to 628.3 m. This gas-bearing unit consists of a fining-upward, channel-fill succession, erosionally overlying an interval of interbedded sandstone and shale. The lack of marine indicators (e.g., burrows, tidal bundles), carbonaceous nature and the presence of a coal seam in a supradjacent bed (Fig. 34) suggest a fluvial origin. The channel-fill deposit is gradationally overlain by two thin coarsening-upward intervals, the uppermost of which is burrow mottled, indicating possible marine influence. The uppermost coarsening-upward succession is erosionally overlain by a thin conglomerate. Vertical burrows extend down from the erosion surface into the underlying sandstone and are infilled with material similar to the matrix of the overlying conglomerate (Fig. 35b, 36). The erosional contact and conglomerate are interpreted as a ravinement surface and an overlying transgressive lag deposit, respectively. The conglomerate is abruptly overlain by an interval of organic-rich, fissile shale that contains thin bentonite beds (Fig. 35a). These shales are interpreted as condensed marine deposits.

The radioactive shales and other prominent log markers within the Fort St. John succession are interpreted as resulting from deposition after, during, and immediately

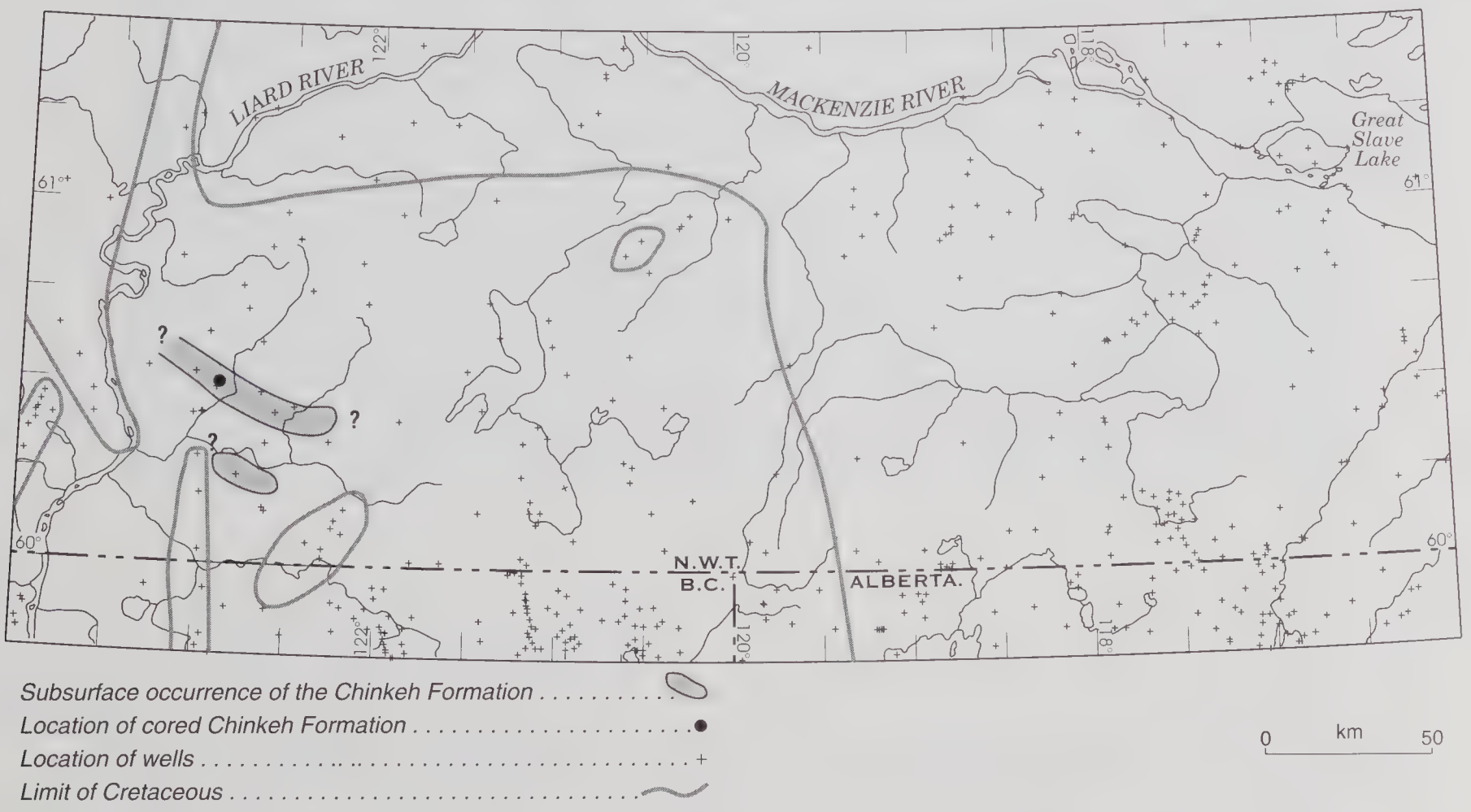

Figure 33. *Occurrence of the Chinkeh Formation in the Great Slave Plain area.*

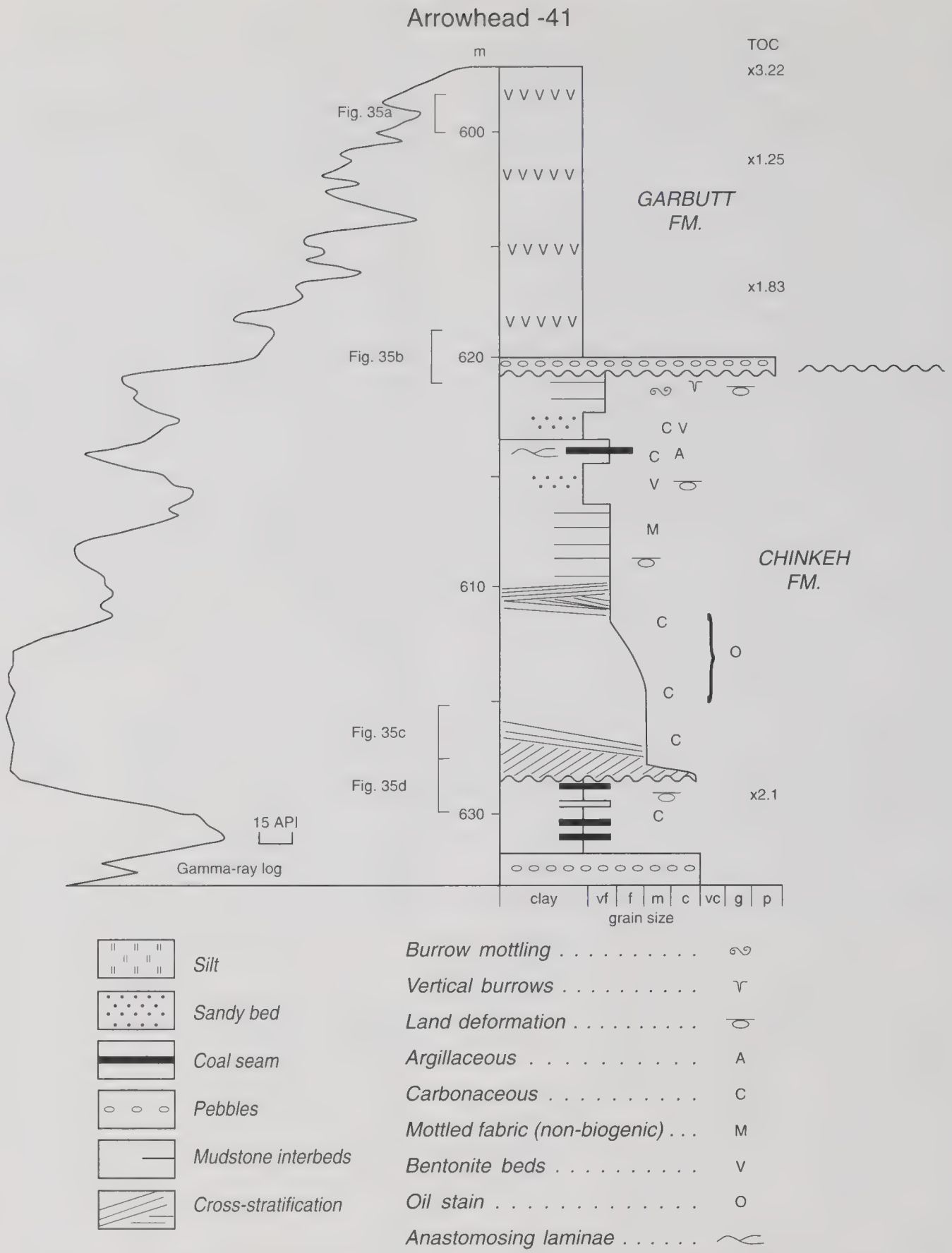

Figure 34. *Graphic representation of the Garbutt and Chinkeh formations in core from the Arrowhead B-41 well. Total organic content is indicated for sample points and the areas covered by photographs in Figure 35 are indicated.*

following major basin-wide transgressions. In this scenario the radioactive shales, and "normal" shales abruptly capping silty or sandy beds represent condensed sections.

From the available data, most of the Fort St. John Group appears to consist of marine sediments in the subsurface. The possible exception is the Chinkeh Formation, which could contain some nonmarine beds. Chinkeh strata in outcrops to the west have been identified as a mixture of marine and nonmarine sediments (Leckie et al., 1991). In the subsurface, Chinkeh sandstones occur in what appears to be a west–northwest-trending, large-scale, erosional feature, at least 100 km long. The width of this feature is less well constrained but must be at least several kilometres. This erosional feature cuts into a long-lived peneplain and formed prior to marine flooding. It has many of the characteristics of an incised-valley system (i.e., an estuary; see the papers in Dalrymple et al., 1994, for a review of such depositional systems).

Figure 35. *Photographs of selected parts of the Garbutt and Chinkeh formations in core from Arrowhead B-41.* ***a.*** *Garbutt Formation. Core depths 598.2 to 600 m. Organic-rich, fissile shale interbedded with bentonite beds (light grey to white). GSC photo 4458-2.* ***b.*** *Contact between the Garbutt and Chinkeh formations (arrow). GSC photo 4458-4.* ***c.*** *Chinkeh Formation. Core depths 625.04 to 627.39 m. Porous sandstone within a channel-fill deposit. GSC photo 4458-10.* ***d.*** *Chinkeh Formation. Core depths 627.39 to 639.8 m. Contact between channel-fill sediments and underlying beds (arrow). GSC photo 4458-12.*

Figure 36. *Detail of the erosional contact between the Garbutt and Chinkeh formations. Note the vertical to subvertical burrows in bioturbated Chinkeh sandstone filled with material similar to the matrix of the overlying conglomerate. GSC photo 4458-16.*

In the plains east of Liard River the thickest known occurrence of the Fort St. John Group is in the Arrowhead L-49 well, where 596.5 m of strata have been identified. This well occurs within an area of prominent thickening of Fort St. John strata, probably a reflection of the known rapid thickening into the adjacent Liard Basin (Fig. 4). Strata thin eastward, as a result of depositional thinning, internal unconformities and pre-Quaternary erosion. A northeast-trending isopach thin in the vicinity of the Celibeta wells (and coincident with the Celibeta structure; Williams, 1977b) coincides with a thick Quaternary cover. In some of the Celibeta wells the Quaternary rests directly on Paleozoic rocks. A similar, locally thick Quaternary section rests erosionally on the Cretaceous of Horn Plateau (Williams 1977a). In both areas the Quaternary deposits fill a channel-like erosional feature.

Not only is there considerable depositional thinning of Fort St. John strata between the Liard Basin and the plains area but detailed correlations of log markers suggest the possibility of at least two major erosional levels (Fig. 12–14). The correlations suggest that much of the Scatter Formation and part of the Garbutt Formation have been removed from the plains area east of the Bovie Fault. The second erosional level is a pre-Fish Scales unconformity, a feature of known regional extent (Leckie et al., 1992). Pre-Fish Scales erosion also tends to erode downsection in an eastward direction, removing equivalents of the Sikanni Formation and the upper beds of the Lepine Formation.

The Fort St. John Group has been dated as Early Albian to Cenomanian (Stott, 1982), with the Albian–Cenomanian contact falling at, or near, the base of the Fish Scales Bed (Leckie et al., 1992). Fish Scales strata have been dated as early Cenomanian by Leckie et al. (1992). Presumably the "normal" shale succession immediately above the Fish Scales Bed (i.e., the remainder of the Fort St. John Group) also is early, to possibly middle, Cenomanian if the overlying Dunvegan is correctly dated as middle Cenomanian (see following discussion).

Regional correlations

Several cross-sections linking the Cretaceous succession in wells of the southern Northwest Territories with some wells in northeast British Columbia and northwest Alberta have been constructed (Fig. 37–39) in order to illustrate possible correlations between these areas. The cross-sections have been constructed to coincide with some of those used by Stott (1982) and Thompson (1977), in order to illustrate newer concepts in correlation. Using log markers as the principle correlation tool (most of the chosen log markers are the expression of flooding surfaces) and noting correlation anomalies and mismatches, regional unconformities are inferred using the principles of sequence stratigraphy (see the papers in Wilgus et al., 1988). Two of the unconformities have already been documented, that between the Paddy and Cadotte members of the Peace River Formation (Leckie and Reinson, 1994), and one below the Fish Scales Bed (Leckie et al., 1992).

It is apparent from the cross-sections and regional geology that that there are at least three major internal unconformities within the Fort St. John Group and equivalent strata. Because of a lack of core control the exact position of the unconformites in the wells is speculative, but the overall trends and correlations suggest that the unconformities should occur close to the positions indicated in Figures 37 to 39.

Correlations indicate that the unconformity between the Paddy and Cadotte formations, within the Peace River Formation, truncates a large amount of the underlying succession in the Great Slave Plain area and northeasternmost British Columbia. This unconformity appears to correlate into the upper Scatter Formation (probably within the Tussock Member), which is consistent with the known major transgressive surface at the top of the Scatter Formation.

An inferred unconformity of regional significance is within the Notikewin Member of the Spirit River Formation. Traced northward from the Peace River area this unconformity also truncates a significant amount of section (Fig. 39). Stott (1982, fig. 5) correlated the Notikewin Member with the upper part of the Bulwell Member of the Scatter Formation. The correlations attempted in the present report cannot substantiate or disprove Stott's (1982) correlation, but based on the available data it seems reasonable.

The third major unconformity is present near the base of the Fish Scales Bed. As previously indicated, the correlations at this level do not favour the presence of Sikanni Formation, or equivalent strata, in the Great Slave Plain area, in contrast to what was implied by Williams (1978). Major eastward downcutting is apparent at the pre-Fish Scales unconformity.

Although the correlations presented here do not negate any of Stott's (1982, fig. 5) regional correlations they do point to a more complex internal stratigraphy than previously presented (Stott, 1982, Fig. 10, 14–16, 18, 20; Thompson, 1977, fig. 4).

Dunvegan Formation

Dunvegan strata consist of interbedded conglomerate, sandstone, siltstone, and shale, and in Great Slave Plain occur to the northwest and southeast of Trout Lake. There, they are mapped as the youngest bedrock unit below the Quaternary cover (Douglas and Norris, 1976). They are also present at the northern extremity of Liard Basin, where the Liard River crosses into the Northwest Territories (Stott, 1982, fig. 3b).

Dunvegan strata are only up to 60 m thick in the Interior Plains. A major problem is the difficulty in distinguishing them from Quaternary sands and gravels that cover a large area of the plains. Also, both units commonly occur behind surface casing in the wells, consequently lithology samples and geophysical logs are lacking. This problem is well illustrated by the lack of identification of Dunvegan strata in wells located where Dunvegan Formation has been mapped. In most wells, the Quaternary has been identified as resting on Fort St. John Group, with only a few wells in which Dunvegan strata have been identified.

The most comprehensive descriptions of Dunvegan strata are from outcrops (Stott, 1982). Stott (1982) described the Sully–Dunvegan contact as transitional in outcrops, and in the subsurface there are both gradational and abrupt contacts (see cross-sections in Stott, 1982; Thompson, 1977).

The age of the Dunvegan Formation in northeast British Columbia is Cenomanian (see discussion in Stott, 1982, p. 70-71), possibly late Cenomanian (Hills et al., 1981, p. 51). However, on a more regional scale, the Dunvegan has been identified as principally middle Cenomanian (Bhattacharya, 1994), which seems to be more consistent with the regional setting.

Kotaneelee Formation

The Kotaneelee Formation is present only in the extreme southwestern Northwest Territories close to where the Liard River crosses the Northwest Territories–British Columbia boundary. It extends only a short distance into adjacent Yukon (Stott, 1982, fig. 3b). These occurrences are at the northernmost end of Liard Basin. Nowhere are there equivalents of the Kotaneelee Formation in the Northern Interior Plains east of Bovie Lake.

Kotaneelee strata consist of shale and siltstone with some interbedded sandstone and a few conglomerate beds. The formation rests erosionally on Dunvegan strata and is overlain by Wapiti strata. Stott (1968) indicated a Santonian age for the formation, whereas on a more regional basis the unit is equivalent to the Santonian to Campanian Wapiabi Formation (see fig. 17.12 in Smith, 1994). The ages indicate a correlation with part of the Little Bear Formation, but probably only the Upper member.

Wapiti Formation

Wapiti strata occur in the same area as the Kotaneelee Formation (Stott, 1982, fig 3b) and are absent in the Northern Interior Plains east of Bovie Lake. The formation consists of interbedded sandstone, siltstone, shale, coal, and some conglomerate. A Campanian to early Maastrichtian age has been indicated for this unit on recent stratigraphic charts (fig. 17.12 in Smith, 1994, and fig. 24.3 in Dawson et al., 1994). If the age assignment is correct the Wapiti Formation would correlate with the East Fork Formation of Mackenzie Plain. Although the basal contact with the Kotaneelee Formation has not been described in any detail (see Stott, 1968), regional considerations suggest it is unconformable.

DISCUSSION

Regional unconformities and other fundamental boundaries

The proposed correlations (Fig. 15) reflect most of the views expressed previously (Dixon 1986, 1993a): that there are fundamental stratigraphic boundaries within the Mesozoic to Tertiary succession. At least ten regionally important transgressive–regressive cycles are identified and/or inferred to be present in Mesozoic and Tertiary strata of the Northern Interior Plains and plateaux based on the identification of unconformities and/or flooding surfaces (Fig. 15). Several additional TR cycles have been identified since the earlier work of Dixon (1986, 1993a). The most significant additions and/or interpretations are: 1) the identification of at least three cycles in the Albian of southern Northwest Territories, and four identified in Peel Plateau, 2) an early to middle Cenomanian TR cycle (i.e., the Sully and Dunvegan formations, 3) the possibility of the regional unconformity between Turonian and Campanian strata identified in the northernmost mainland Northwest Territories occurring within the Little Bear Formation, possibly between the Lower and Upper members of the formation, and 4) the recognition that there is a late Campanian to middle Maastrichtian TR cycle, not recognized by Dixon (1986. 1993a).

Finer scale TR cycles are apparent in the coarsening-upward units seen in such formations as the Mahony Lake, Trevor and Little Bear, but their regional significance is difficult to judge because correlations beyond the local scale are virtually impossible with the presently available data.

A Late Aptian to Early Albian transgression, which was widespread throughout western North America, is reflected in the presence of sandy beds at the base of the Cretaceous succession of the Interior Plains. These basal transgressive beds characteristically consist of interbedded shale, siltstone, and sandstone, in which glauconite, ironstone and a brown coloration are common features. These beds in turn are abruptly overlain by a shale-dominant succession. This latter contact is interpreted as a flooding surface, possibly a maximum flooding surface.

Although the Albian superficially appears to be a continuous succession throughout much of the Northwest Territories, there is sufficient evidence from internal correlations in the Fort St. John Group of the Great Slave Plain and seismic data from Peel Plateau to indicate the presence of several TR cycles. (Fig. 12–14, 28). In the Fort St. John Group of the southern Northwest Territories there is at least one significant unconformity within the Albian, interpreted as being near the top of the Scatter Formation. This unconformity appears to have developed during the Middle Albian (i.e., pre-*Gastroplites* zone), based on the known age of the overlying Lepine Formation (Stott, 1982). A lower unconformity is also inferred from correlations into adjacent British Columbia and northwest Alberta (Fig. 37–39) but which has been truncated in the succession of Great Slave Plain. The unconformities and/or flooding surfaces identified in the Albian of the southern Northwest Territories and adjacent provinces divide the succession into at least three TR cycles.

How the events in the Fort St. John Group correlate with the four TR cycles identified in the Albian of Peel Plateau remains a problem. Poor age control in the Albian of Great Bear Plain makes it difficult to identify similar horizons, although regional stratigraphic considerations suggest that, if present, the equivalent horizons should occur in the Mahony Lake Formation. The radioactive shale interval seen in several wells in Great Bear Plain is tentatively correlated with the Scatter marker of Great Bear Plain. This is consistent with its position well above the basal transgressive beds and below Middle Albian strata of the Mahony Lake Formation.

The next major boundary is between Albian and Cenomanian strata, which in the study area is between the Arctic Red and Slater River formations, and within the Fort St. John Group (near the base of the Fish Scales Bed) and Trevor Formation. However, the available age determinations and regional context suggest that there are two cycles within the Cenomanian to Turonian; an early to middle Cenomanian cycle (Sully to Dunvegan formations), and a late Cenomanian to Turonian cycle (Slater River Formation to lower member, Little Bear Formation).

In the Great Slave Plain and Liard Plateau areas the Albian to Cenomanian succession is shale-dominant, but correlations of the Fish Scales Bed in the area and into adjacent British Columbia and Alberta indicate the presence of a regionally extensive Albian–Cenomanian hiatus.

The cross-sections in Mackenzie Plain (Fig. 8, 9) clearly show the removal of Albian strata below the Slater River Formation in the vicinity of Tertiary Hills, along an approximately north–south trend. This trend coincides with the position of the Keele Arch (Cook, 1975; Yorath and Cook, 1981; Williams, 1989), a long-lived tectonic feature reactivated in the mid-Cretaceous, probably because of tectonic stress emanating from the Cordilleran orogen. Also coincident with the Keele Arch are the presence of thick, quartz arenites at the base of the Slater River Formation, although they tend to be located more toward the centre and eastern margin of the arch (e.g., the Police Island L-66 and Old Fort Point E-30 wells). West of the arch, the basal Slater River is less sandy and contains more interbedded sandstone and shale.

However, the unconformity between Albian and Cenomanian strata is not everywhere so prominent. In the Peel Plateau this boundary is within the Trevor Formation. Although no firm evidence exists as to the position of such a boundary, the presence of a thick, bentonitic, Turonian shale within the Trevor Formation, similar to Cenomanian and Turonian shale elsewhere in the north, and resting abruptly on Albian sandstone and shale, suggests its presence.

In Mackenzie Plain the Slater River to Little Bear succession represents an overall transgressive–regressive (TR) cycle of sedimentation that apparently spans the Turonian to Santonian and may be as old as late Cenomanian. This is in contrast to the stratigraphic succession in other parts of northernmost mainland Canada (Dixon, 1986, 1993a), where a major regional discontinuity exists between Turonian and Santonian strata. The expression of this unconformity also is seen in strata of southwestern Northwest Territories and adjacent British Columbia, where the Santonian–Campanian Kotaneelee Formation rests unconformably on the middle Cenomanian Dunvegan Formation. If such an event affected Slater River–Little Bear sedimentation it is possible that it is within the sandstone and shale succession of the Little Bear Formation. The apparently consistent stratigraphic horizon, and the marked contrast between the Lower and Upper members could signify a major stratigraphic boundary. However, without better biostratigraphic and lithostratigraphic control the presence or absence of a discontinuity will remain unresolved.

The next fundamental boundary is that between the Little Bear and East Fork formations, here interpreted as a flooding surface. If correctly interpreted there should be a ravinement and/or unconformity surface somewhere within the uppermost beds of the Little Bear Formation. This latter interpretation is supported by the presence of a truncated Slater River Formation and a much reduced sandstone succession assigned to the Little Bear Formation in the Police Island L-66 and Windy River A-53 wells. This much-thinned sandstone could be interpreted as transgressive beds above a major unconformity and below the flooding surface at the base of the East Fork Formation. Where a full Little Bear succession is present, the identification of an unconformity in the uppermost beds is speculative. Based on the available paleontological data, the flooding surface separates Santonian from late Campanian beds (Sweet et al., 1989).

The biostratigraphic data from the Brackett Basin indicate that there is a late Campanian to middle Maastrichtian succession not identified in the Beaufort–Mackenzie Basin (Dixon, 1993a).

Although a major unconformity exists between upper Maastrichtian and older strata in the northern Richardson Mountains (Dixon, 1986, 1993a), a corresponding event in the Upper Cretaceous of the Brackett Basin is not as apparent from presently available data. In fact, the paleontological data of Sweet et al. (1989) suggest deposition throughout the Maastrichtian. However, the lithostratigraphic divisions used by Sweet et al. (1989) may have clouded the issue and Yorath and Cook's (1981) original contention of an implied unconformity between East Fork and Summit Creek strata probably is valid. If there is an unconformable relationship between East Fork and Summit Creek strata, especially in the Police Island area, it is possible that the first occurrence of major conglomeratic beds could be an indicator of such a relationship. In Sweet et al.'s (1989, fig. 5) cross-section (and especially sections SLA-85-13 and 86-2) the first significant conglomerate beds appear in the informal biozone of *Porosipollis porosus*. This zone is dated as mid or late Maastrichtian. Strata of the Cuesta Creek Member, Tent Island Formation, which lie above a Maastrichtian unconformity in the northern Richardson Mountains contain a palynological assemblage similar to Sweet et al.'s (1989) *P. porosus* Zone (Sweet, 1978).

The Cenomanian succession in the southern Northwest Territories and adjacent Yukon and British Columbia contain strata interpreted as indicating the presence of a transgressive–regressive cycle not recognized in the more northerly Cretaceous occurrences. The Sully Formation, including the Fish Scales Bed, and the Dunvegan Formation are early to middle Cenomanian in age (if correctly correlated to the Fish Scales Bed of northern Alberta and northeast British Columbia; Leckie et al., 1992). The oldest Upper Cretaceous strata in the Mackenzie Plain appear to be late Cenomanian (Slater River Formation). The available data could be interpreted as indicating that the Sully and Dunvegan formations are part of the oldest Upper Cretaceous TR cycle so far identified in the Northern Interior Plains and adjacent areas.

Lithostratigraphic correlations into northeast British Columbia

Figures 37 to 39 illustrate the proposed correlations between the Cretaceous of the southern Northwest Territories with that of northeast British Columbia and northern Alberta. The bases for the correlations are the use of prominent log markers, such as flooding surfaces or other unique features, and the inferred presence of unconformities. These types of correlations do not always correspond to lithostratigraphic subdivisions. However, some general lithostratigraphic correlations can be inferred from the log correlations (Fig. 40).

The Upper Aptian to Lower Albian beds of the Gilmore Lakes Member, Langton Bay Formation, the Martin House Formation and the Chinkeh Formation are equivalent to the

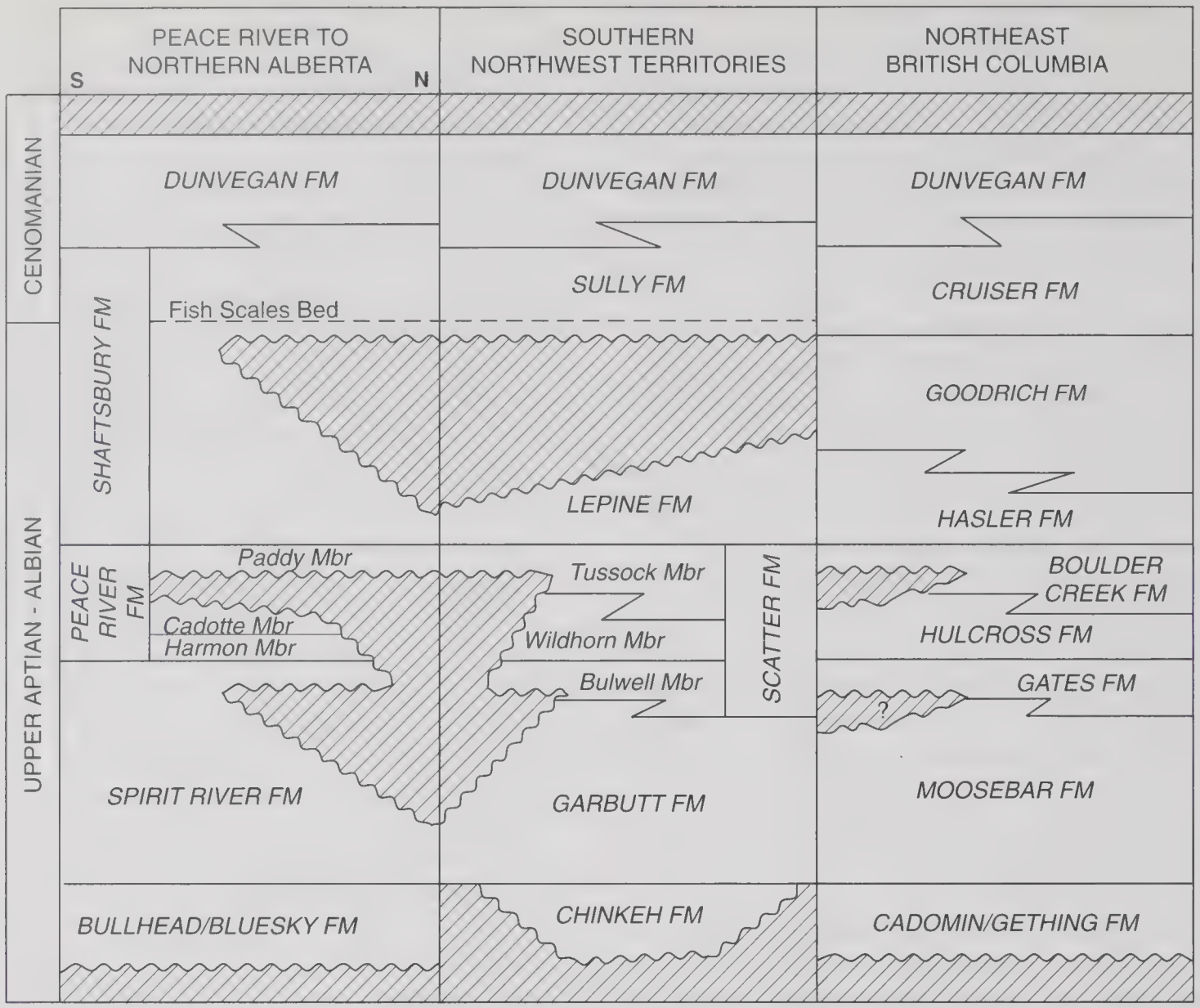

Figure 40. *Correlation chart of lithostratigraphic units between southern Northwest Territories, northeast British Columbia, and northern Alberta. The possible unconformity within the Gates Formation is speculative and is based on recorrelation of Stott's (1982) subsurface sections. These unpublished correlations indicate truncation of strata at this level.*

Bullhead Group, which includes the Cadomin and Gething formations. The Garbutt and Scatter formations are equivalent to Spirit River and Peace River groups. Correlation of specific intervals between these latter units requires more thorough analysis, but it would appear that the Hulcross, Harmon and Wildhorn units are correlative. If that is correct then the Tussock sandstone would be correlative with the Paddy–Cadotte and Boulder Creek units. Correlative units in the more northern plains would include the Arctic Red and Mahony Lake formations, lower part of the Trevor Formation, Crossley Lakes Member (Langton Bay Formation), and the Horton River Formation.

The Lepine, Sikanni and Sully formations are equivalent to the Shaftesbury, Hasler, Goodrich, and Cruiser formations. As previously discussed, the Sully Formation contains an interval equivalent to the Fish Scales Bed present throughout northern Alberta. These successions apparently have no equivalents north of Great Slave Plain.

The youngest Cretaceous strata are essentially extensions into the southern Northwest Territories and southeast Yukon of units mapped in northeast British Columbia: the Dunvegan, Kotanelee and Wapiti.

Paleogeography

The Albian to Paleocene succession reflects the extensive marine inundation of the craton in the late Aptian–Early Albian (Williams and Stelck, 1975) and the subsequent infilling of the Peel Trough, Brackett, Great Bear, and Liard foreland basins. Marine influences can be found in strata as young as the early to middle Maastrichtian East Fork Formation, but in late Maastrichtian strata only nonmarine beds are present (Sweet et al., 1989), suggesting a retreat of the interior seaway to the continental margins and alluvial deposition on the craton, within interior basins. The Late Cretaceous to Paleocene record of sedimentation is not as continuous as Yorath and Cook (1981) implied; rather, there were several transgressive–regressive events of regional magnitude (Dixon, 1993a). Whether the resulting patterns of sedimentation were caused by eustasy or tectonism is debatable (Dixon, 1993a, b) but the proximity of the

sediments to the active Cordillera tends to favour a strong tectonic influence.

As a possible indication of tectonic control it is interesting to note that erosion at the intra-Scatter and pre-Fish Scales unconformities in Great Slave Plain cuts downward to the east (i.e., cratonward), whereas the foreland basin (i.e., Liard Basin) with its more complete section is west of this downcutting trend.

During the Jurassic and earliest Cretaceous most of the Northern and Western Interior Plains apparently were areas of nondeposition. Depositional basins were present in the northern Yukon, Mackenzie Delta area, westernmost Alberta, northeast British Columbia, southern Saskatchewan, and parts of southwestern Manitoba (Dixon, 1992; Smith, 1994). During this phase of deposition the Cordilleran foredeep in western Canada was a relatively narrow depositional area (Smith, 1994). In northern Canada there is very little record of Jurassic to earliest Cretaceous foredeep deposition; the bulk of the preserved sediments indicates epicontinental sedimentation (Young, 1973; Dixon, 1992). The Late Aptian–Early Albian transgression transformed the paleogeography of western Canada: large areas of the Interior Plains became marine depositional realms and large deltas formed (Smith, 1994). The Albian and younger phases of deposition record the cratonward migration of the Cordilleran foredeep.

Late Aptian to Albian

The bulk of the preserved Upper Aptian to Albian succession in the Northern Interior Plains consists of marine sediments, principally shale. Upper Aptian to Lower Albian strata of the Anderson, Horton, Peel, Great Bear and Great Slave plains, and Peel Plateau reflect deposition in a narrow, cratonic seaway (Fig. 41, 42). The western boundary was the Cordillera Foldbelt, and the eastern the Canadian Shield, although in both cases the exact eastern and western limits are not accurately known because of post-Albian erosion. Remnants of nonmarine Albian strata are found in the outlier of the Redstone River area (Mackenzie Mountains; Blusson, 1971), about 100 km from the nearest marine Albian strata in Mackenzie Plain. On the eastern side of the seaway, nonmarine beds were deposited on Anderson and Horton plains during the Late Aptian to Early Albian and were derived from the area of the Coppermine Arch.

Albian nonmarine pollen and spores are preserved in xenoliths within kimberlite intrusions of the Grassy Lakes area, on the Canadian Shield, about 200 km east of the presently preserved Albian succession (Nassichuk and McIntyre, 1995). This occurrence attests to the once extensive nature of Albian sedimentation. Also, the Grassy Lakes occurrence indicates that there may have been an eastward-directed re-entrant or bulge in the Albian area of sedimentation, coincident with the arcuate bulge of the Mackenzie Mountains. This occurrence of nonmarine strata is consistent with the presence of only marine strata in the easternmost Albian outcrops around Great Bear Lake, Horn Plateau and Great Slave Plain.

The Late Aptian to earliest Albian transgressive phase of sedimentation was followed by a long period of overall regression for the remainder of the Albian (Fig. 42), punctuated by several major transgressive events. However, only a limited amount of coarse grained, littoral, siliciclastic sediments have been preserved in the Interior Plains. These are in the Trevor and Mahony Lake formations. Presumably some of the nonmarine strata in the Redstone River inlier of the Mackenzie Mountains are Middle and Upper Albian. Although the smaller scale coarsening-upward cycles seen in the Trevor and Mahony Lake formations are a reflection of transgressive–regressive sedimentation, their significance as regional or subregional events is unknown. These coarse grained deposits were derived from the Cordilleran foldbelt. The amount of Shield-derived coarse grained sediments remains unknown because of a lack of coarse grained sediments in the eastern areas of occurrence. In fact much of the presumed Middle to Upper Albian sediments in these eastern areas are marine shales, implying that the eastern shoreline was considerably farther east than the present outcrop edge.

In the area of Liard Plateau the Albian succession records the presence of regionally correlatable Albian transgressive–regressive cycles. At least three cycles can be recognized in the Albian part of the Fort St. John Group. The oldest consists of the Chinkeh Formation, Garbutt Formation and Bulwell Member of the Scatter Formation; the second consists of the Wildhorn and Tussock members of the Scatter Formation, and the third consists of the Lepine and Sikanni formations. Although these cycles are best identified in the mountains of the Liard Plateau, the abrupt flooding surfaces that mark the tops of these coarsening-upward cycles can be traced into the predominantly shale and siltstone succession of Great Slave Plain (Fig. 12–14). These TR cycles of the Liard Plateau and Great Slave Plain are almost entirely marine (Stott, 1982; Leckie et al., 1991).

During the earliest phase of Late Aptian to Early Albian transgression, there was a broadly positive area in the Great Slave Plain area that extended into northeasternmost British Columbia and northernmost Alberta. Earliest deposition is recorded as infill of long, broad estuaries, to the east of which was a low-lying land area (Fig. 41). This land area was soon inundated and covered by a thin veneer of silty transgressive beds followed by sediments of the subsequent regression. This Albian paleogeographic feature overlies the Early Devonian Tathlina High (see Meijer Drees, 1994). Although overlying an older tectonic element, the Albian

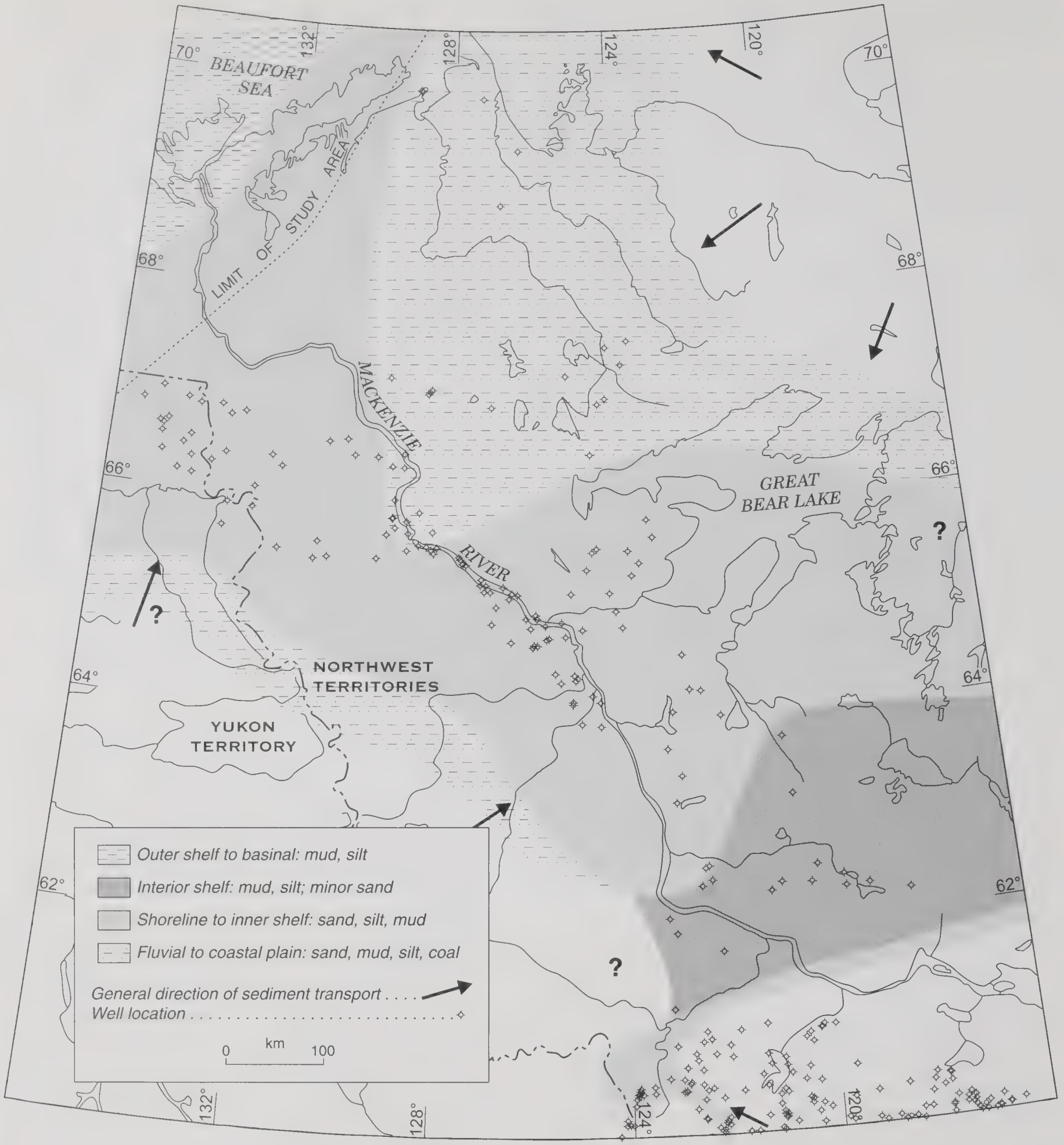

Figure 41. *Late Aptian paleogeography.*

expression of the Tathlina High was over a much broader area than it was in the Early Devonian. The western boundary of this Albian high is marked by rapid thickness increase in the Albian succession (Fig. 13, 37). This rapid change corresponds approximately with the Bovie Fault Zone. To the north and south, the thickness change is more gradual (Fig. 10, 39).

Reactivation of the Tathlina High during the Albian is evident by the eastward downcutting of strata at the sub-

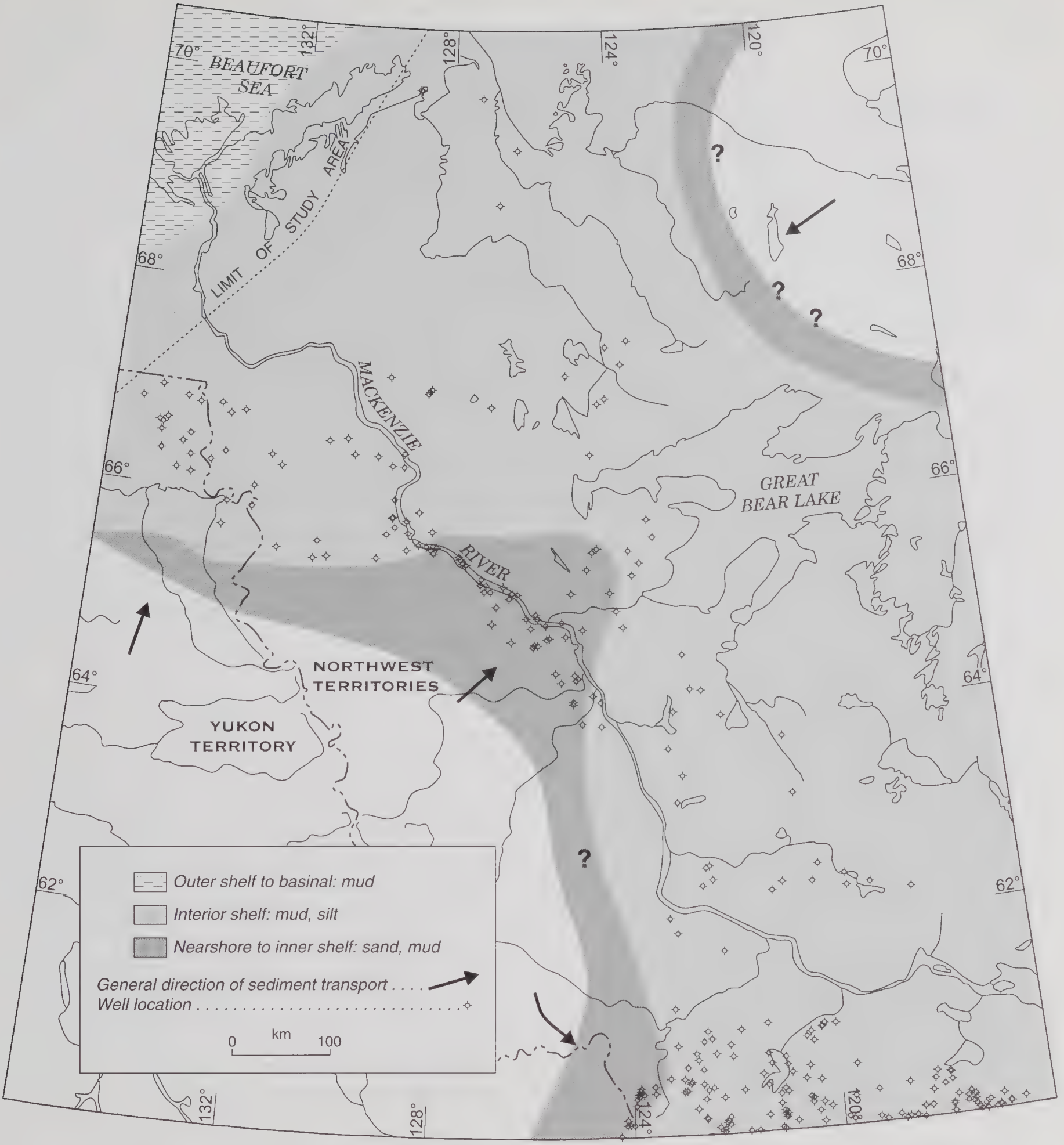

Figure 42. *Middle to Late Albian paleogeography.*

Lepine unconformity. This phase of uplift appears to have been some time in the Middle and Late Albian. Sediment eroded from the uplift was probably transported westward into Liard Basin, northward into the Great Bear Basin and southward to the Peace River area.

In Peel Plateau, four TR cycles of sedimentation have been recognized. After the initial transgression, which produced a basal sandy transgressive succession, sedimentation was characterized by inner to middle shelf mud deposition (Arctic Red Formation). Only during the final cycle did coarse grained, littoral siliciclastics (Albian

part of the Trevor Formation) prograde over the earlier shelf muds.

Cenomanian–Turonian

The end of Albian deposition was marked by the development of a regionally extensive unconformity (Dixon, 1992). Conditions within the interior seaway during the Cenomanian and Turonian were characterized by low oxygen content, as is evident by the common occurrence of organic-rich shale (i.e., the Fish Scales Bed, the basal shale of the Slater River Formation, and the Boundary Creek Formation in northern Yukon; Dixon 1992).

Most of the preserved Cenomanian–Turonian succession in Mackenzie, Great Bear, Anderson and Horton plains consists of marine shale (Sully and Slater River formations), with only locally developed sandy transgressive sandstones over the Keele Arch. Cenomanian and Turonian regressive sandstone beds are present in the upper part of the Trevor Formation of Peel Plateau, the Dunvegan Formation of the southern Northwest Territories, and may be present in the Lower member of the Little Bear Formation. Trevor and Little Bear strata appear to be predominantly marine, whereas the Dunvegan is mostly nonmarine (Stott, 1982). The area of Dunvegan deposition may have been a major delta complex. Presumably some of the nonmarine strata in the Redstone River outlier in Mackenzie Mountains (Blusson, 1971) are Cenomanian to Turonian, and represent a more proximal facies to the basin-fill of the interior seaway.

The available paleontological data and determined stratigraphic relations indicate that the Cenomanian–Turonian succession contains at least two regional TR cycles.

Erosion at the sub-Fish Scales Bed unconformity in the Great Slave Plain area points to eastward downcutting (Fig. 13) and the reactivation of the Tathlina High in Late Albian time.

Santonian–Campanian

The interior seaway continued to exist during the Santonian and Campanian, with similar depositional trends to those present during the Albian to Turonian (Fig. 43). Eastern depositional limits are poorly defined because of a lack of preserved strata.

In the Anderson and Horton plains, Santonian–Campanian strata of the Smoking Hills Formation rest unconformably on Albian beds. Elsewhere in the Interior Plains the unconformable relationship is less readily identified. As previously reported, the equivalent unconformity should fall within the Little Bear Formation and is interpreted as being approximately between the Lower and Upper members. It is possible that some of the nonmarine strata in the Redstone River outlier (Blusson, 1971) may include some Santonian–Campanian beds. In the southernmost Northwest Territories, the Kotaneelee Formation was deposited during the Santonian–Campanian.

The Smoking Hills Formation is an organic-rich shale deposited in an oxygen-deficient outer shelf to slope environment (Dixon, 1993a). These sediments are in marked contrast to the underlying Early Albian nonmarine to nearshore sediments and the Middle Albian shelf sediments, indicating that the eastern shoreline of the interior seaway had migrated much farther east. A large area of eroded Santonian–Campanian strata separates the Smoking Hills occurrences from the nearshore marine strata of the Upper member, Little Bear Formation, in Mackenzie Plain. These latter sediments were derived from the Cordillera foldbelt to the southwest, grading northward and eastward into shalier beds. Nonmarine strata in the Redstone River outlier represent a more proximal facies of the Santonian–Campanian foreland basin-fill, and the clastics of the Kotaneelee Formation may have been part of a deltaic depositional system.

Late Campanian–middle Maastrichtian

A late Campanian transgression is recorded by the Little Bear–East Fork contact, herein interpreted as a flooding surface. Evidence for an associated unconformity may be present in the Police Island L-66 and Windy River A-53 wells, where a thin sandstone succession below the East Fork shale rests erosionally on the Slater River Formation. This late Campanian to middle Maastrichtian TR succession has a very limited preservational area; it is present in the vicinity of Tertiary Hills in the Mackenzie Plain, and in Anderson and Horton plains, within the Mason River Formation. In the latter area the Mason River Formation rests abruptly on the Smoking Hills Formation. A correlative succession is present in the predominantly nonmarine, probably deltaic, Wapiti Formation of Liard Plateau.

Although the Campanian to Maastrichtian strata are of limited distribution the facies trends are similar to those of earlier depositional trends in the interior seaway. The Mason River Formation represents middle to outer shelf shales, remote from the source terrains. East Fork shales are interpreted as representing inner shelf shale that was gradationally succeeded by nearshore to littoral, shale-to-sandstone coarsening-upward cycles of the Sandstone member.

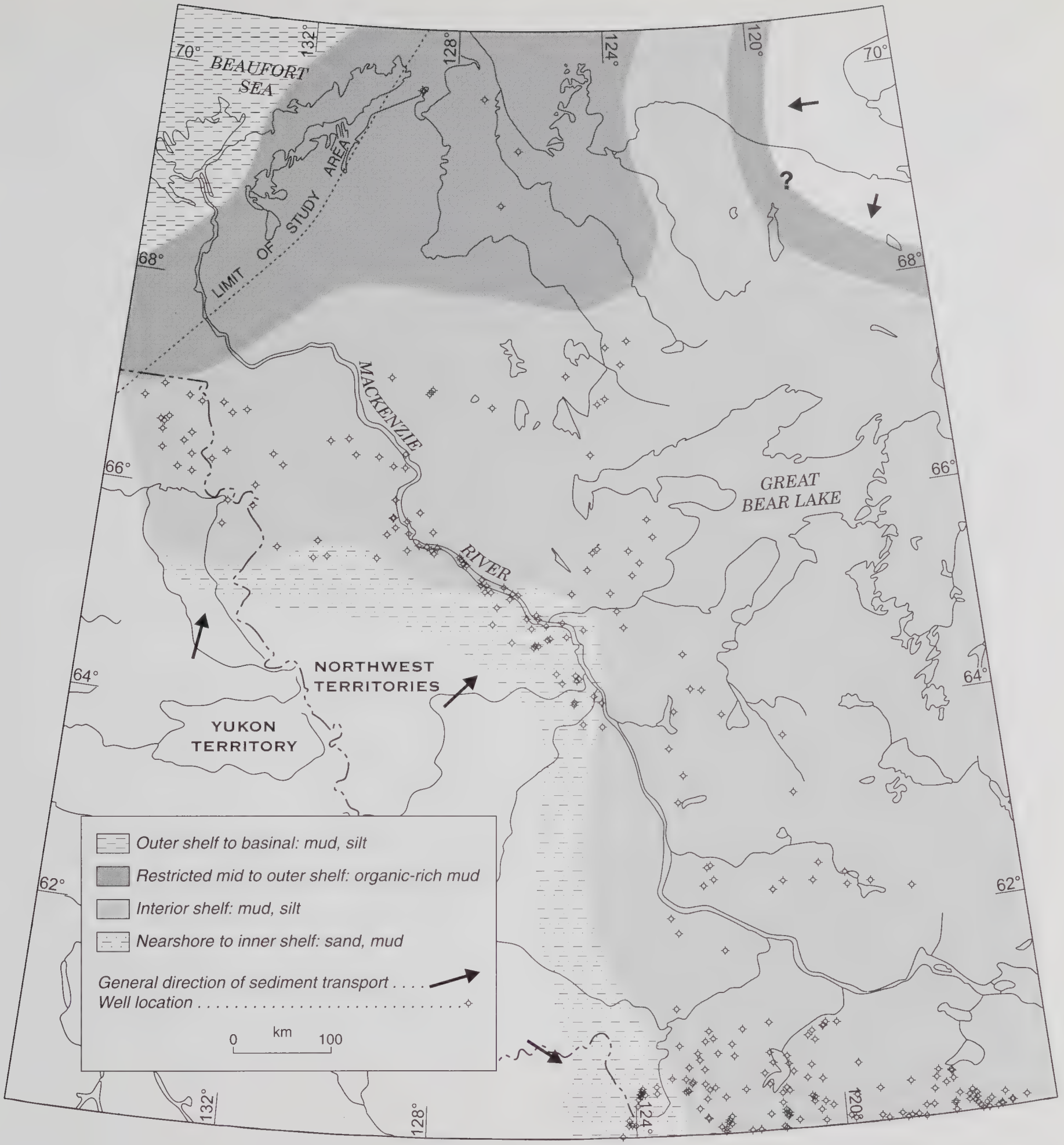

Figure 43. *Santonian–Campanian paleogeography.*

Late Maastrichtian–Paleocene

A major facies shift is recorded in the late Maastrichtian to Paleocene succession. Deposition was preceded by the development of a major unconformity. Although the bulk of the preserved strata is limited to the Tertiary Hills of Mackenzie Plain, the presence of nonmarine strata of the Summit Creek Formation resting on older marine beds attests to the major facies shift.

Duk-Rodkin and Hughes (1994) interpreted the nonmarine realm of Summit Creek deposition as an eastward-flowing fluvial system that traversed the Shield on its way to the Labrador Sea (they called this the "Atlantic Drainage" on their fig. 2, op. cit.; Fig. 44). Their work builds upon earlier ideas presented by MacMillan (1973). The interpretation is further supported by the presence of Paleocene nonmarine palynomorphs in xenoliths of the Grassy Lake kimberlites (McIntyre, pers. comm., 1994; Nassichuk and McIntyre, 1995) located 200 km to the east on the Shield.

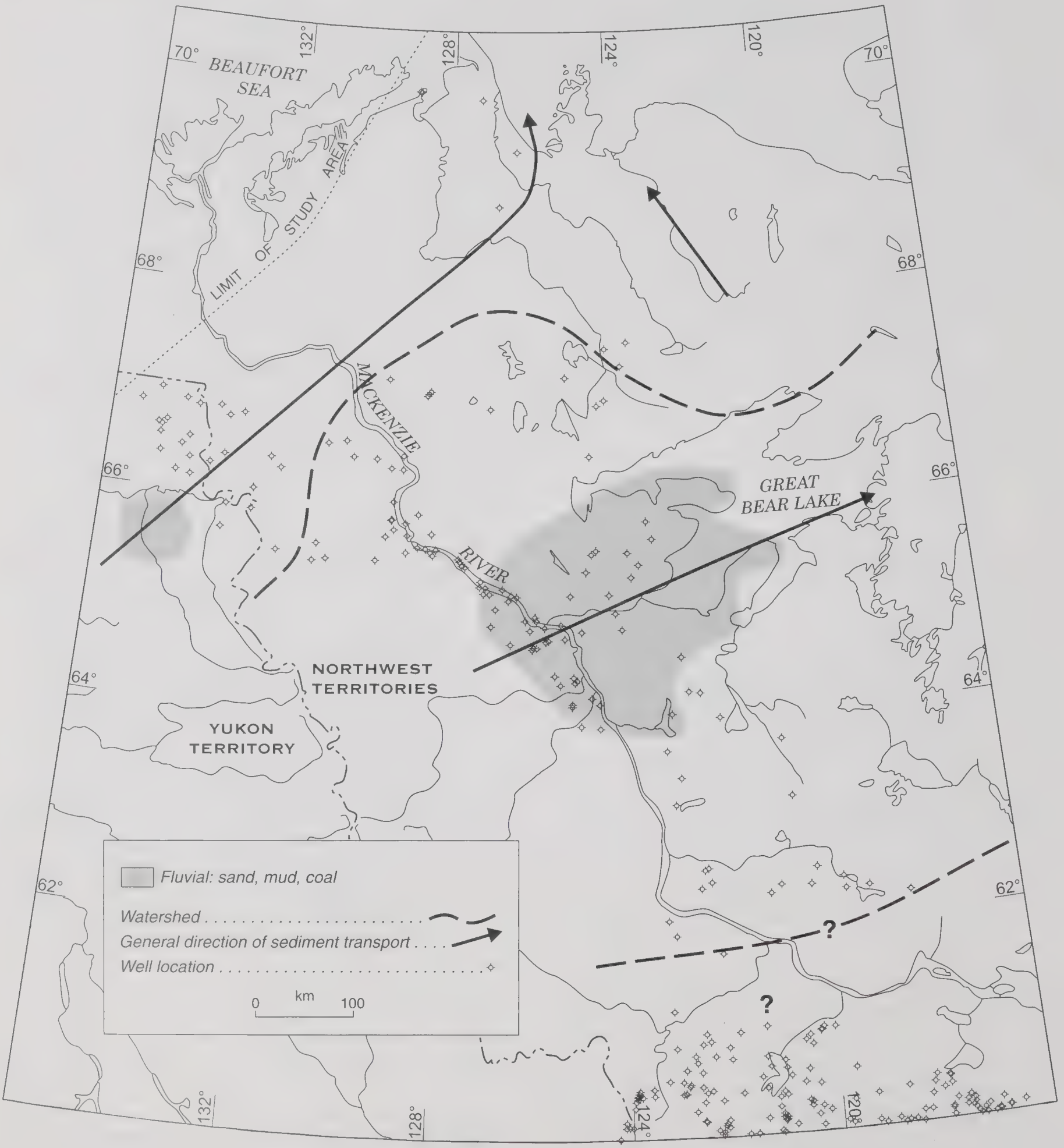

Figure 44. *Paleocene paleogeography (adapted from Duk-Rodkin and Hughes, 1994).*

Duk-Rodkin and Hughes (1994) also suggested that there was a drainage system in the Anderson and Horton plains area that flowed into the Beaufort Sea. There are no preserved upper Maastrichtian to Paleocene strata in these areas but there are extensive age-equivalent deposits in the adjacent Beaufort–Mackenzie Basin (Dixon et al., 1992).

Pliocene

Within the Interior Plains there is a notable lack of upper Paleocene to Miocene strata. Any that were deposited have been subsequently eroded. In Anderson Plain there is a remnant of a presumed Pliocene succession. These Pliocene beds consist of unconsolidated gravel and coarse grained sand resting unconformably on the Mason River Formation. Originally these beds were correlated to the Miocene "Beaufort Formation" of Banks Island (Yorath and Cook, 1981). However, recent work on the Tertiary of the Beaufort–Mackenzie and Banks Island areas (Dixon et al., 1992) indicates that these gravels are probably Pliocene in age and correlate to the Iperk Sequence of the Beaufort–Mackenzie Basin and equivalent beds on Banks Island. As such they are the landward feather-edge of a thick Pliocene deltaic complex (Dixon et al., 1992).

ECONOMIC GEOLOGY

Oil and gas potential

Source rocks

Most of the published geochemical data is available only from the Fort Norman area of Mackenzie Plain (Snowdon, 1990), with vitrinite reflectance data in Feinstein et al. (1991). Unfortunately neither report includes data from the Albian succession of this area and there are few data points from within the East Fork and Summit Creek formations. Data on the organic content of the Smoking Hills Formation of Anderson Plain is available in Dixon et al. (1992). Leckie et al. (1991) evaluated the maturation of the Fort St John Group in the northern part of the Liard Basin, using a limited dataset.

Because of the lack of organic geochemical data three wells from the Northwest Territories were chosen for Rock-Eval analysis: the Arctic Red F-47, Mahony Lake I-74, and Arrowhead B-41. These wells are located in three prominent basins and/or tectono–stratigraphic domains. Arctic Red F-47 is located in the foreland basin of Peel Trough; Mahony Lake I-74 in the Great Bear Basin, and Arrowhead B-41 on the more cratonic area under Great Slave Plain. A fourth well, from the Liard Basin (a foreland basin) of northeast British Columbia (Viscount a-77-d/94-O-11), was examined in order to present a more complete representation of the various tectonic and stratigraphic settings.

In Arctic Red F-47 the penetrated Cretaceous succession is entirely Albian (the Trevor and Arctic Red formations). Organic carbon content ranges from poor to moderately good, and declines downsection as maturity increases. The Trevor Formation has between 0.57 to 2.2 per cent organic carbon, but generally falls between 1.4 and 1.8 per cent. These values probably reflect the presence of organic debris in the marginal marine to deltaic sediments. Arctic Red strata have an organic content between 1.0 and 1.5 per cent to log depth 5470 ft., below which organic carbon is generally < 1.0 per cent. The mature oil zone begins near the surface, according to the Tmax data, becoming overmature at about 5600 ft. Lowermost strata in the Arctic Red Formation and the whole of the Martin House Formation are within the overmature zone.

In Mackenzie Plain, the bulk of the East Fork and Slater River shales contains about one per cent organic carbon and is immature to marginally mature. At the base of the Slater River Formation there is an organic-rich interval coincident with a highly radioactive shale. Organic values up to 6.84 per cent have been recorded from this interval in the Little Bear L-21 well (Snowdon, 1990) and up to 8.24 per cent from a cored interval in the Bluefish A-57 well (unpublished data, Snowdon, pers. comm., 1995). The high Hydrogen Index and low Oxygen Index values suggest Type I or II organic matter (Snowdon, 1990), indicating an oil-prone source rock. However, in the Bluefish well the Tmax indicates an immature to marginally mature source.

The Little Bear Formation has a highly variable organic carbon content, due in large part to the presence of coal and coaly material. Summit Creek strata contain numerous coal seams and coaly material, and can be anticipated to have a high organic carbon content. However, it is assumed that the Little Bear to Summit Creek interval is thermally immature, based on the marginal maturity of the more deeply buried Slater River Formation.

In the East Mackay B-45 well, oil was recovered from Paleozoic rocks immediately below the Cretaceous Slater River Formation. Geochemical properties suggest the oil was derived from the Slater River Formation (Yorath and Cook, 1981, p. 46; M. Fowler, pers. comm., 1995).

In Anderson Basin, Smoking Hills strata are organic rich, with 2 to 12 per cent organic carbon. However, because of the shallow burial depth these strata are immature to marginally mature. Low to moderately high Hydrogen Indices and high Oxygen Indices indicate Type II and III organic matter (Snowdon, unpublished data). These latter indices do not suggest a particularly good oil source-rock.

The Albian to Upper Cretaceous succession in Mahony Lake I-74 of Great Bear Basin generally has an organic carbon content of < 1 per cent, with a thin Upper Cretaceous interval ranging up to 1.91 per cent. Organic maturity ranges from marginal near the surface, to mature at the base of the Cretaceous. A mixture of Type II and III organic matter is present.

Two samples from core in the Albian Arctic Red Formation of Great Bear Basin (St. Charles Creek H-41: unpublished data, L.R. Snowdon, pers. comm., 1995) gave organic carbon values of 0.65 and 1.92, with low Oxygen and Hydrogen indices, indicating a mixture of organic types. Tmax value averaged about 440° C, indicating the rocks are within the mature zone for oil generation.

Rock-Eval data from Arrowhead B-41 on Great Slave Plain indicate generally low organic carbon values (< 1 per cent) for the Lepine Formation. However, at the top of the Lepine Formation, organic content is quite high, with values up to 3.4 per cent. Unfortunately this interval is behind surface casing and the gamma-ray log character is not available. At the base of the Lepine Formation there is a radioactive shale with organic content slightly higher than the bulk of the formation (between 1.0 and 1.2 per cent). Organic content tends to be generally higher in the Scatter, Garbutt, and Chinkeh formations, with values ranging from 1.4 to 2.0 per cent. High Production Indices within the Scatter Formation could indicate staining. The Cretaceous succession in B-41 is immature in the Lepine Formation to marginally mature within the Chinkeh to Scatter interval. Organic matter of Types I, II, and III are present throughout the Cretaceous succession.

Four samples were analysed from the Arrowhead B-41 core: three from a radioactive shale (the Lower Albian Garbutt Formation) above the Chinkeh Formation, and one from a shale within the Chinkeh Formation. Those from the Garbutt Formation have an organic carbon content ranging from 1.25 to 3.22, and moderate Hydrogen Indices and low Oxygen Indices, indicating a mixture of Type I and II organic matter. Tmax values range from 426 to 439° C, indicating a maturity that could range from marginally mature to mature for oil generation. The shale from within the Chinkeh Formation has an organic carbon content of 2.1 per cent, low Oxygen and moderate Hydrogen Indices and a Tmax of 439° C. The moderately high organic content is consistent with the carbonaceous nature of the shale. These data indicate a moderately good source rock with a mixture of Type I and II organic matter within the mature zone of oil generation.

Only the Albian part of the Fort St. John Group was penetrated in the Arrowhead B-41 well. Younger strata in Great Slave Plain include the Upper Cretaceous Fish Scales Bed, which in Alberta has a high organic content (Leckie et al., 1992). However, shallow burial depths in Great Slave Plain probably preclude the generation of much hydrocarbon from these beds.

Farther west, in the Liard Basin, the Fort St John Group has been buried more deeply, and Tmax data from the Viscount a-77-d well in northeast British Columbia indicate that the Cretaceous section ranges from immature near surface into the peak oil generation window. In general, the organic content of the Cretaceous succession is < 1 per cent although some isolated intervals have slightly higher values. Two radioactive shales are potential oil source rocks: one occurs at the base of the Garbutt Formation and the other at the base of the Lepine Formation. These two shales have moderately high organic carbon contents (1.11 to 1.63 per cent) and high Hydrogen Indices. In general, the Cretaceous succession contains a mixture of Type II and III organic matter. Within the lower Scatter Formation a zone of high Production Indices could suggest some oil staining.

Reservoir rocks

The Martin House Formation, Langton Bay Formation, the Scatter and Chinkeh formations of the Fort St. John Group, the basal sandstone of the Slater River Formation, and sandstones of the Little Bear and Summit Creek formations could be prospective reservoirs. The petrophysical characteristics (based on log parameters, cuttings samples, and core – where available) of the Martin House, Scatter and basal Slater River sandstones generally indicate poor quality reservoirs. However, there are locally developed reservoir quality sandstones in these formations.

Good porosity is present in some Martin House sandstones in the Hume River wells of Peel Plain and some wells in the Lost Hill Lake area of Great Bear Plain. The basal sandstones of the Slater River Formation in the Old Fort Point E-30 and Police Island L-66 wells have excellent porosity and permeability. Unfortunately, drillstem tests show the sandstones in these two wells to be water bearing. Although many of the Little Bear and Summit Creek sandstones have good reservoir properties they are exposed to the surface and probably have been subject to freshwater recharge.

Based on the marginal maturity and organic type in the Slater River source rock it is unlikely that large volumes of oil have been generated. It is probable that some oil was released, some of which probably flowed to surface out of the potential Cretaceous reservoirs, or was degraded by freshwater influx. The possibility of trapping oil from the Cretaceous source rock within Paleozoic strata is a possible play concept, as exemplified by the East Mackay B-45 oil

recovery. Alternatively, oil generated from Paleozoic source rocks (e.g., the Canol shale) could be trapped in Cretaceous sandstones, especially in the Martin House and basal Slater River formations. In the latter two formations, the sandstones tend to be underlain and overlain by shale, providing good seals to vertical migration of fluids. However, over large areas of the Interior Plains these beds are exposed and lateral migration of fluids out of, or an influx of fresh water into the reservoirs may have occurred. If traps in these Cretaceous sandstones are to be found they will probably be in Mackenzie Plain, Peel Plateau, and possibly the deeper buried parts under the Great Bear Plain.

Reservoir quality sandstones generally are lacking in the Cretaceous of Great Slave Plain although at the perimeter of the Liard Basin there are several sandstone units (Chinkeh and Scatter formations) within the thick, shale-dominant succession of the Fort St. John Group that have reservoir potential. Leckie et al. (1991) identified the Chinkeh Formation as a possible reservoir target. It occurs at the base of the Fort St John Group and is overlain by a thick succession of relatively impermeable shale. Gas has been recovered in Chinkeh strata in the Arrowhead B-41 well, located in the Northwest Territories. A thick, well developed Chinkeh Formation tested 113 269 m^3/d of gas from a very porous and permeable interval between 622 and 628 m. Chinkeh sandstone is best developed in a west–northwest-trending belt between Petitot C-60 and Arrowhead N-02 (Fig. 33). Elsewhere in Great Slave Plain the basal part of the Fort St. John Group is a thin, silty to sandy shale interval with poor reservoir potential. Only a few wells have been drilled in the northern (i.e., within the Northwest Territories and Yukon) part of the Liard Basin (e.g. Kotaneelee B-38, Pointed Mountain P-24) and they contain no Chinkeh sandstone. Here, shale beds of the Fort St. John Group rest directly on older beds.

Other potential sandstone reservoirs in the Fort St. John Group may occur in the Bulwell and Tussock members of the Scatter Formation. Although the best known development of these sandstones in the Fort St. John Group is in northeast British Columbia, the possibility exists that they could have reservoir potential in the Yukon and Northwest Territories part of the Liard Basin. However, equivalents of the Scatter Formation in the subsurface of the Great Slave Plain tend to be very silty to shaly, although cleaner sandstones are present locally.

Coal

The only known strata that contain significant thicknesses of coal occur within the Summit Creek Formation of the Mackenzie Plain, especially in sections adjacent to Police Island. In the latter area, cumulative thicknesses of 30 m or more, and individual beds up to 12.1 m, have been noted (Sweet et al., 1989). The coal varies in rank from lignite to high volatile C bituminous, generally low-rank coals. The high-energy fluvial style of deposition ascribed to the Summit Creek Formation (Sweet et al., 1989) is not conducive to lateral continuity of coal beds. These deposits are not economic at present, even for local usage, because the oil reserves at nearby Norman Wells are a far more efficient fuel source.

Thin coal seams and carbonaceous shales also have been noted in the Upper Aptian to Lower Albian Langton Bay Formation of Anderson Basin (Yorath and Cook, 1981). In equivalent strata as far south as the Hume wells of Peel Plain (i.e., Martin House Formation in the Hume I-66 and N-10 wells) thin seams of coal or coaly material have been noted in core. In the Hume N-10 there is a 1.7 m thick coal bed. Correlation of the coal in Hume N-10 into nearby wells indicates a reasonably large area of occurrence. These widely spaced occurrences of coal in Upper Aptian–Lower Albian strata indicate a large area of potential coal occurrence. Also, these potential coal occurrences would be at relatively shallow depths and in some instances they could occur around the perimeter of Cretaceous outcrop.

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SW

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Little Bear
I-70

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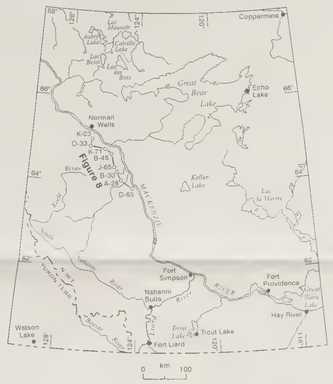
N — S

18 Kilometres	39 Kilometres	20 Kilometres	37 Kilometres	12 Kilometres	21 Kilometres	36 Kilometres

Dodo Canyon	Mirror Lake	Bluefish	East Mackay	Tate	Stewart	Keele River	Dahadinni
K-03	**O-33**	**K-71**	**B-45**	**J-65**	**B-30**	**A-28**	**D-65**



For legend see Figure 9

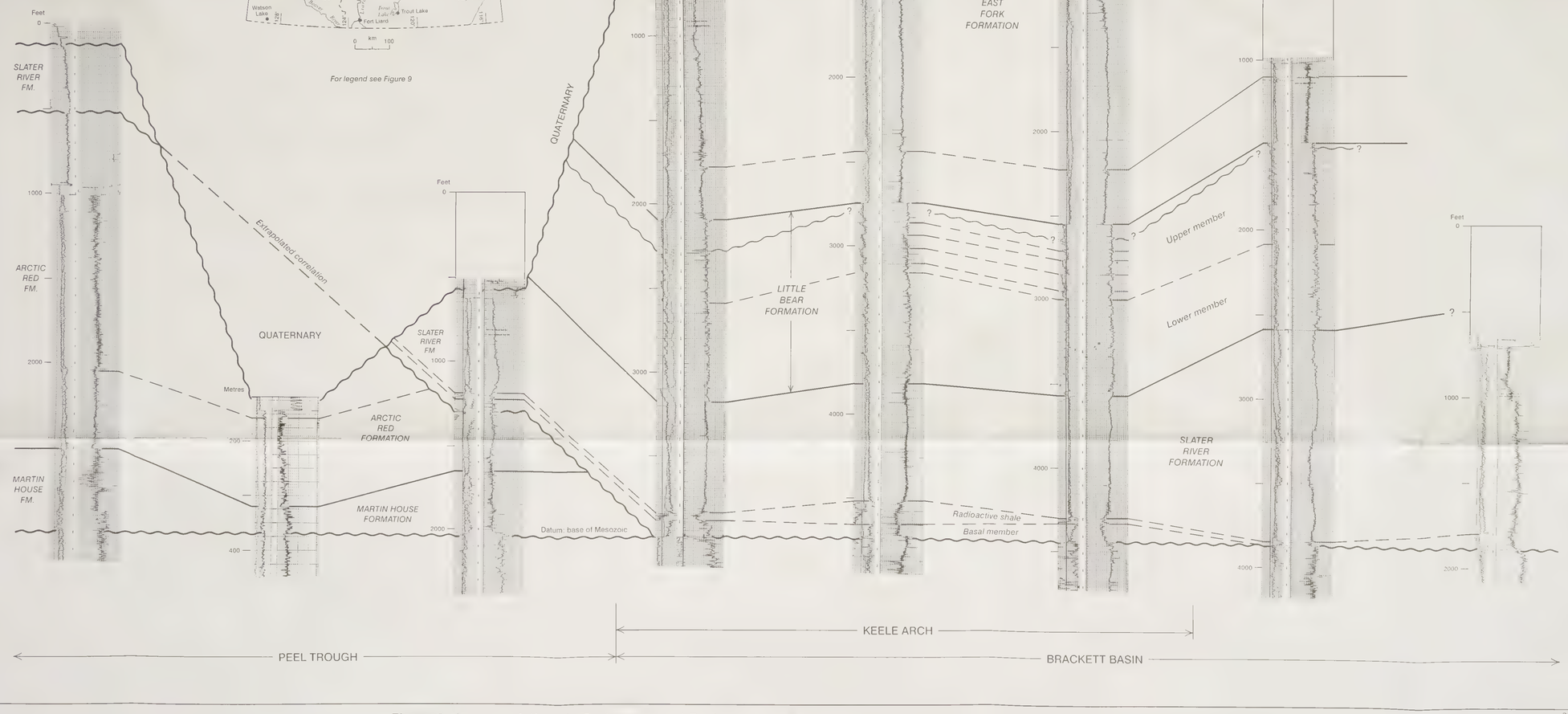


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Figure 8. Log correlations in Cretaceous and Tertiary strata, Mackenzie Plain: Dodo Canyon K-03 to Dahadinni D-65.

Canada

Figure 8
(Figure 9 on reverse)
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NE — SW

Losh Lake G-22	19 Km	Lost Hill Lake F-62	30 Km	Russell M-07	16 Km	Grey Goose N-70	32 Km	Wolverine Creek D-61	48 Km	Old Fort Point E-30	20 Km	Police Island L-66	21 Km	East Mackay B-45	17 Km	Little Bear I-70

LEGEND

Major unconformity .....

Formation boundary .....

Intraformational correlation .....

Questionable interpretation ..... ?

All logs are sonic/gamma ray except where noted

Geology by J. Dixon

To accompany GSC Bulletin 536 by J. Dixon

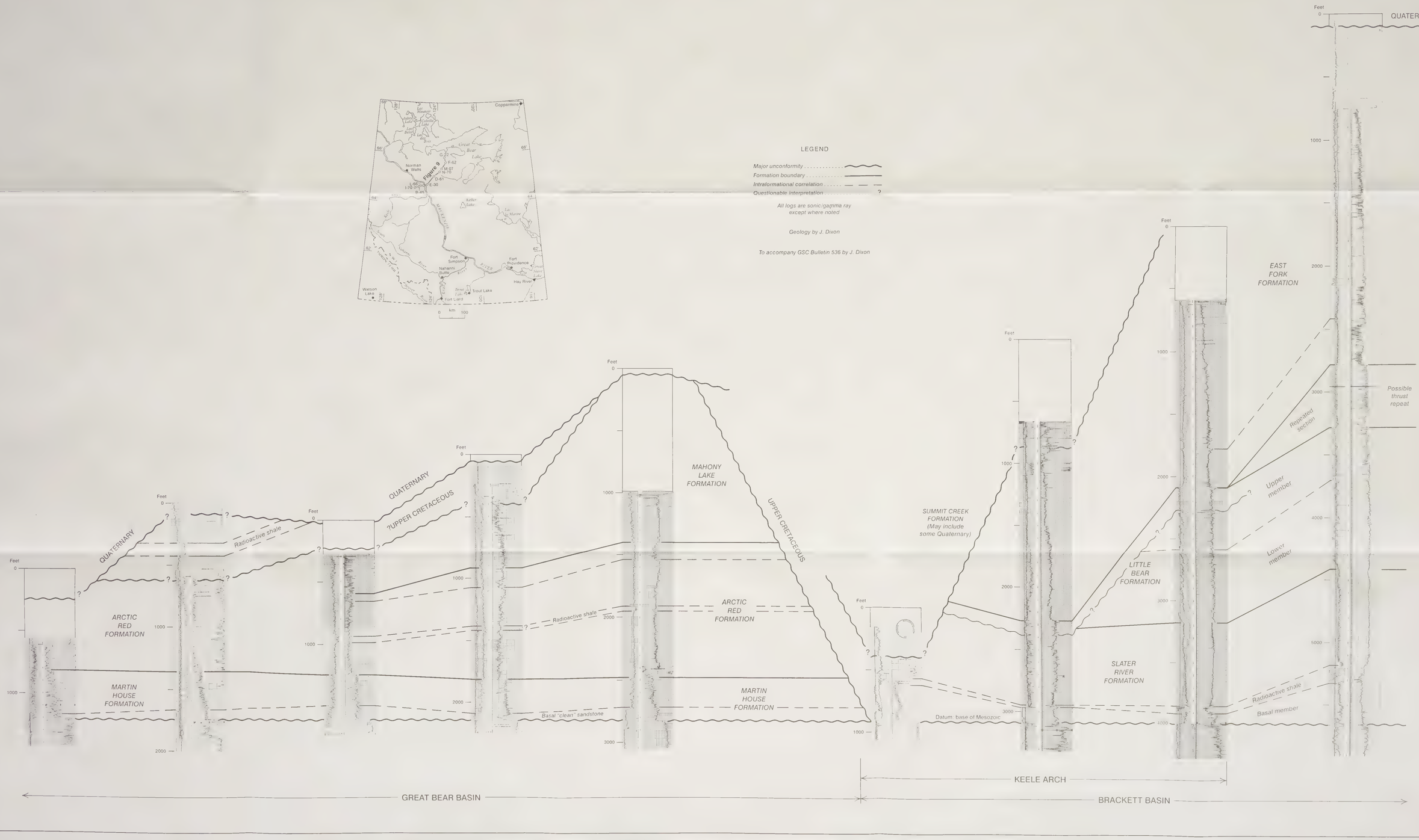

Figure 9. Log correlations in Cretaceous and Tertiary strata, Mackenzie Plain to Great Bear Plain: Losh Lake G-22 to Little Bear I-70.

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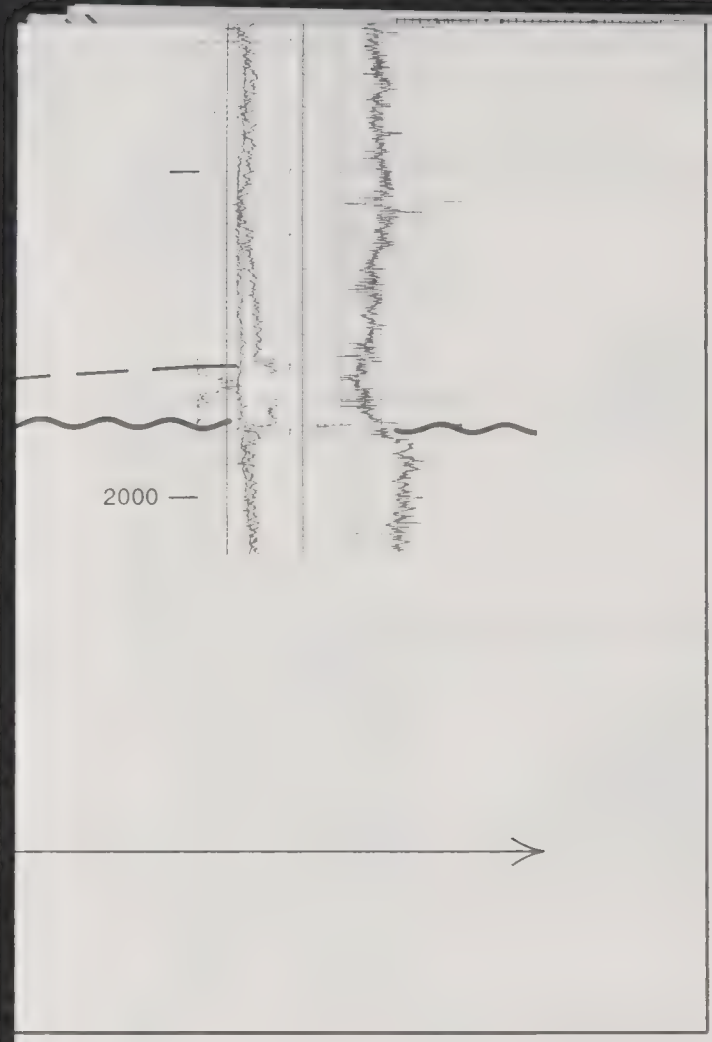

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LEGEND

Major unconformity . . . . . ~~~

Formation boundary . . . . . ———

Intraformational correlation . . . . . — — —

Questionable interpretation . . . . . ?

All logs are sonic/gamma ray
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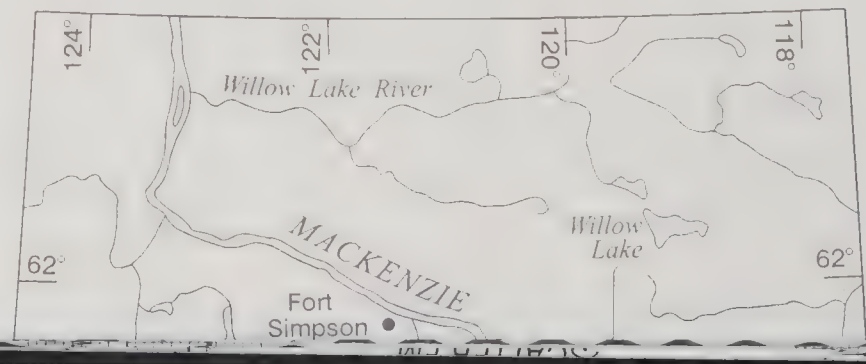

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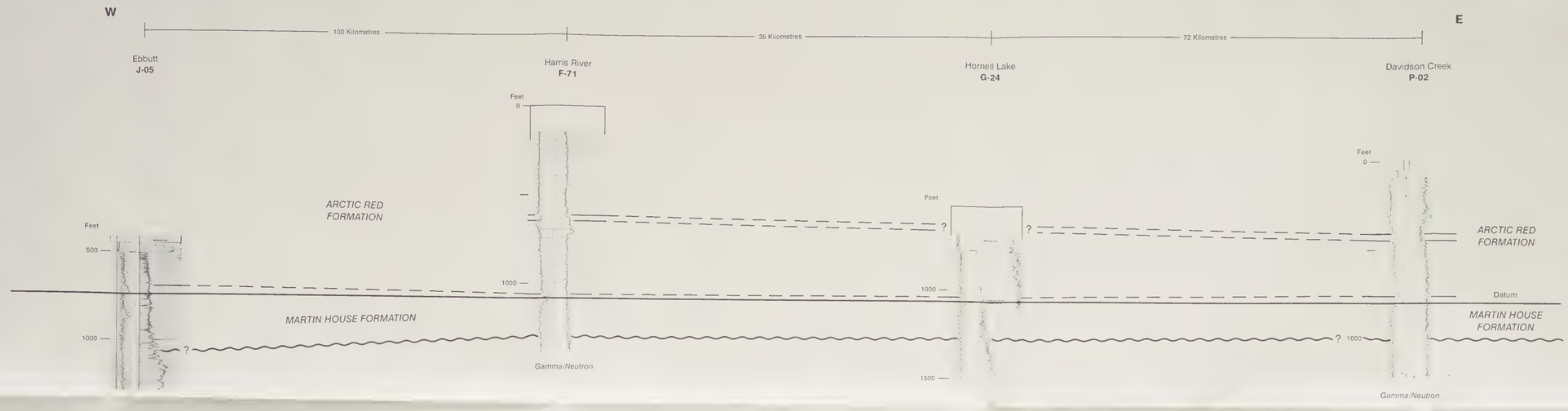

Figure 11. Log correlations in Cretaceous strata, Horn Plateau area: Ebbutt J-05 to Davidson Creek P-02.

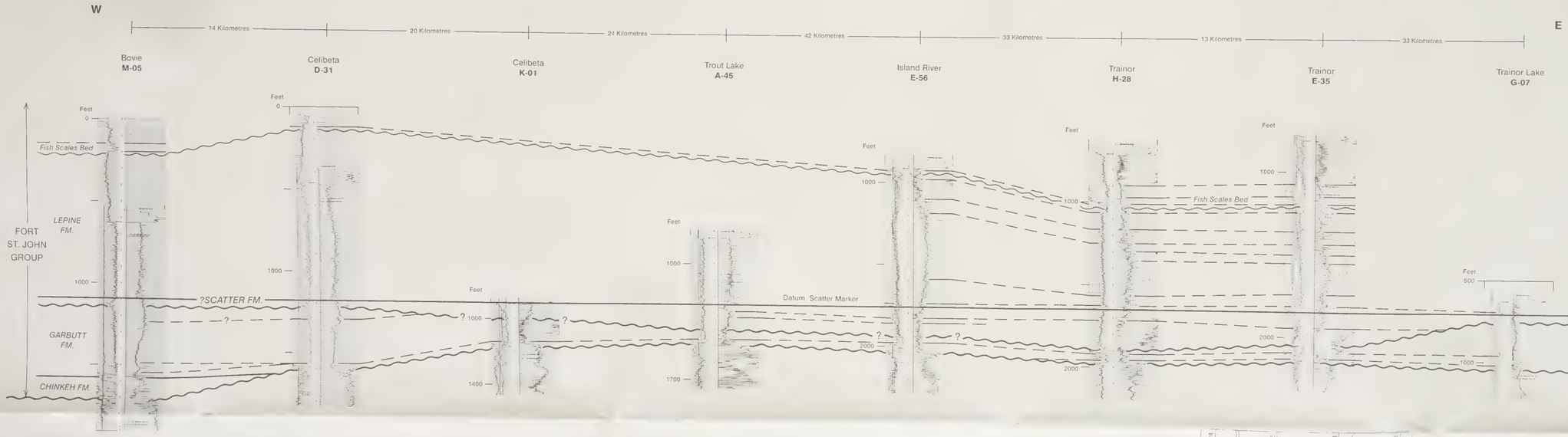

Figure 12. Log correlations in Cretaceous strata, Cameron Hills area: Bovie M-05 to Trainor Lake G-07.

LEGEND

Major unconformity

Formation boundary

Intraformational correlation

Questionable interpretation ?

All logs are sonic/gamma ray except where noted

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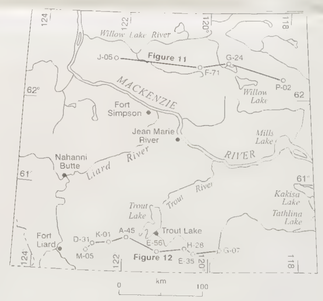

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Figures 11, 12
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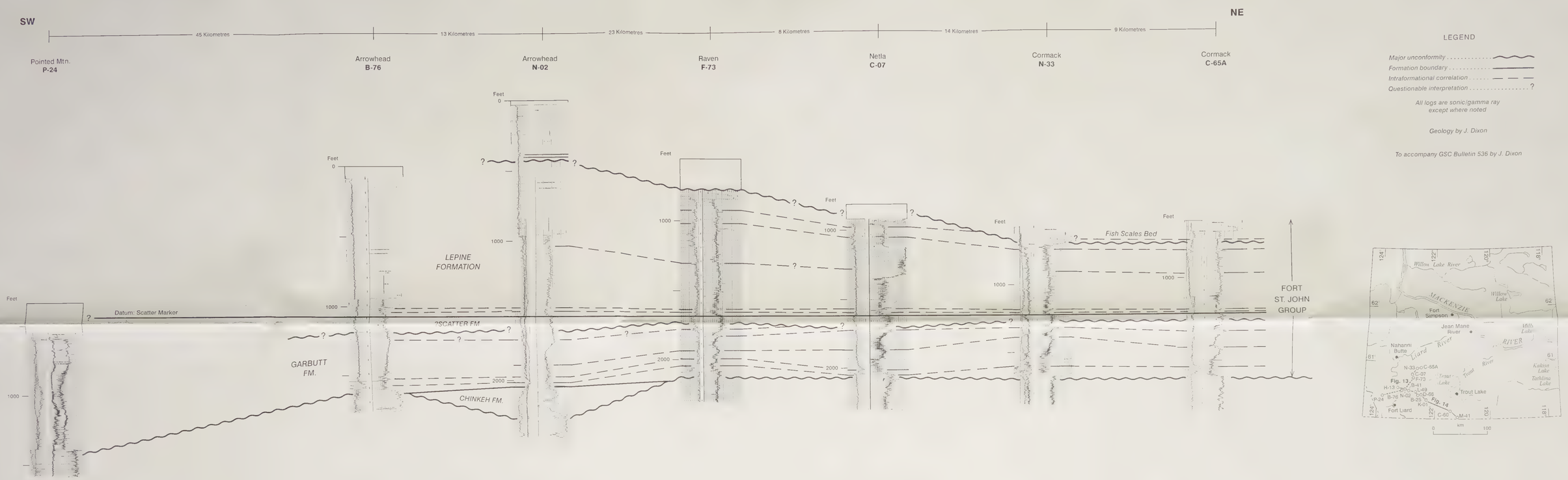

Figure 13. Log correlations in Cretaceous strata, Liard Plateau to Cameron Hills: Pointed Mountain P-24 to Cormack C-65A.

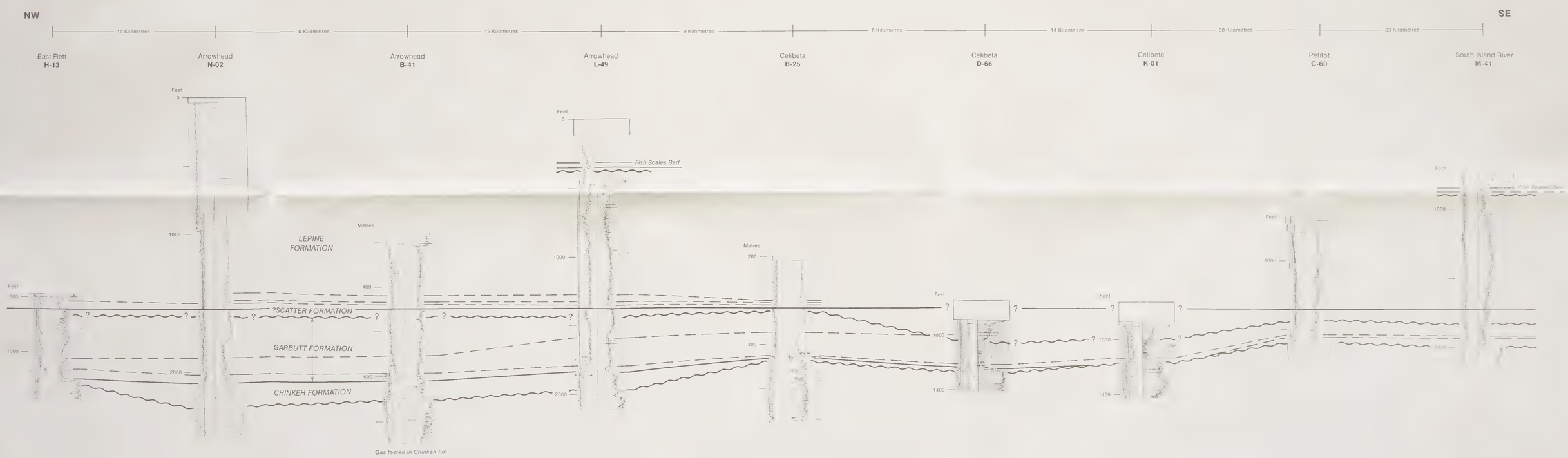

Figure 14. Log correlations in Cretaceous strata, Cameron Hills area: East Flett H-13 to South Island River M-43.

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Figures 11, 12
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E

Kilometres

Carcajou
L-24

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W — E

Peel River L-01	25 Kilometres	Peel River K-76	17 Kilometres	Peel River K-09	18 Kilometres	Peel River M-69	46 Kilometres	Taylor Lake K-15	26 Kilometres	South Peel D-64	75 Kilometres	Arctic Red F-47	63 Kilometres	Hume River L-09	31 Kilometres	Carcajou L-24

LEGEND

Major unconformity

Formation boundary

Intraformational correlation

Questionable interpretation ?

Intervals equivalent to seismostratigraphic units in Figure 28 ① — ⑤

All logs are sonic/gamma ray except where noted

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To accompany GSC Bulletin 536 by J. Dixon

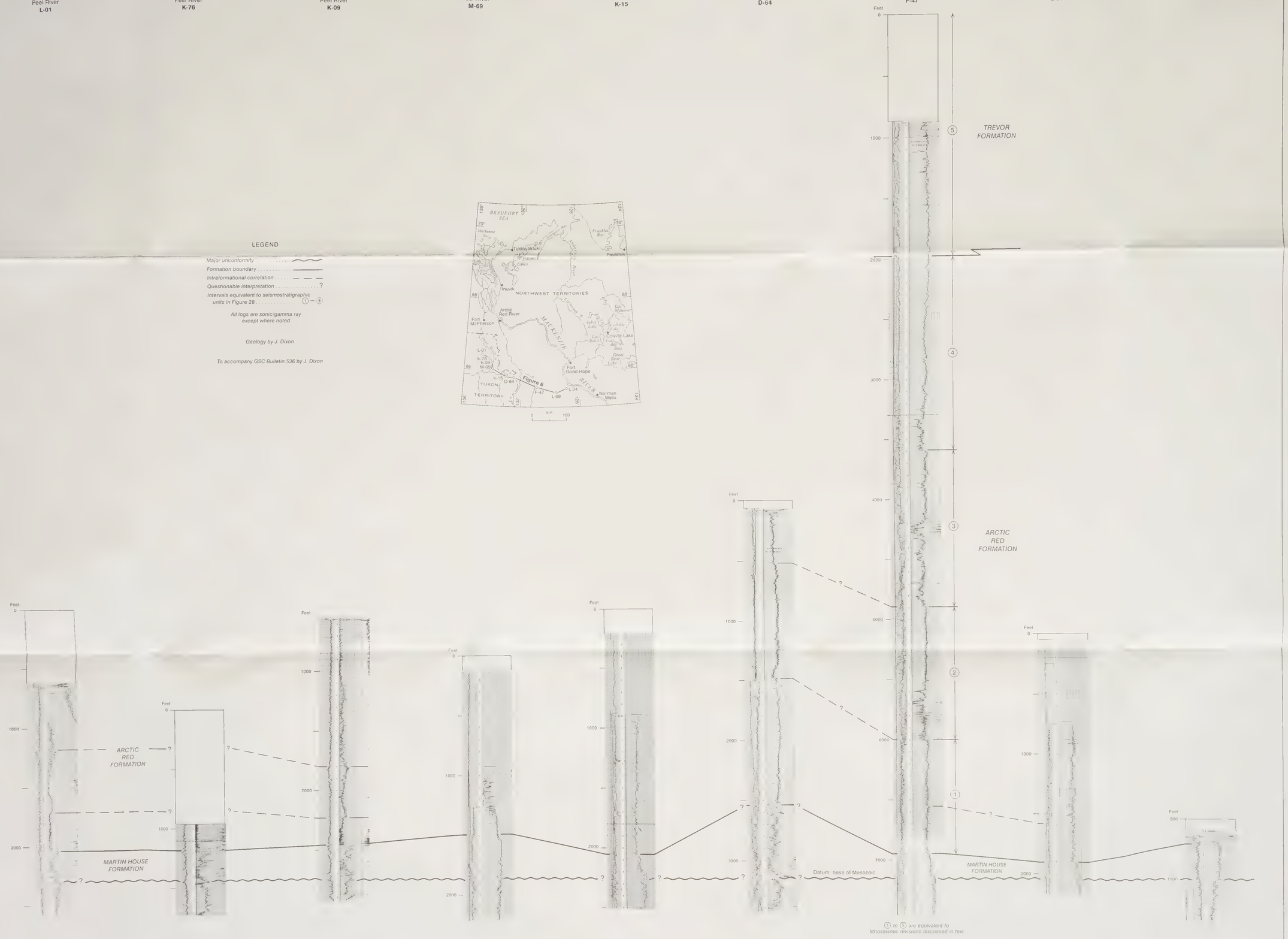
Feet
TREVOR FORMATION
ARCTIC RED FORMATION
MARTIN HOUSE FORMATION
Datum: base of Mesozoic
① to ⑤ are equivalent to lithoseismic divisions discussed in text

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Figure 6. Log correlations in Cretaceous strata, Peel Plain and Plateau: Peel River L-01 to Carcajou L-24.

Canada

Figure 6
(Figure 38 on reverse)

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W — E

65 Kilometres	16 Kilometres	11 Kilometres	22.5 Kilometres	40 Kilometres	21 Kilometres	6 Kilometres
Dunedin **a-75-E**	Viscount **a-77-D**	Tattoo **a-26-B**	Kleneth **c-15-I**	Playmate **b-6-G**	Komie **d-51-A**	Cabin **b-40-A**	Ekwan **a-55-G**

?KOTANEELEE FORMATION

DUNVEGAN FORMATION

SULLY FORMATION

SIKANNI FORMATION

LEPINE FORMATION

SCATTER FORMATION

GARBUTT FORMATION

CHINKEH FORMATION

Datum: Scatter Marker

Radioactive Marker 3

Radioactive Marker 1

Casing

Fish Scales Bed (FSB)

Fish Scales Bed

LEGEND

Major unconformity

Formation boundary

Intraformational correlation

Questionable interpretation ?

All logs are sonic-gamma ray except where noted

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To accompany GSC Bulletin 536 by J. Dixon

Published 1996

Figure 38. Correlation of Cretaceous strata in wells from northeast British Columbia: Dunedin a-75-E to Ekwan a-55-G.

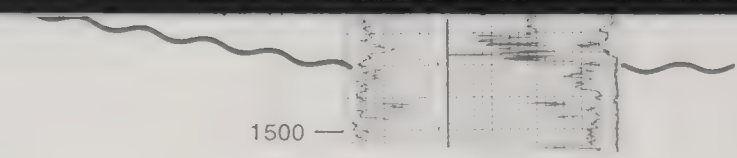

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Figure 38
(Figure 6 on reverse)

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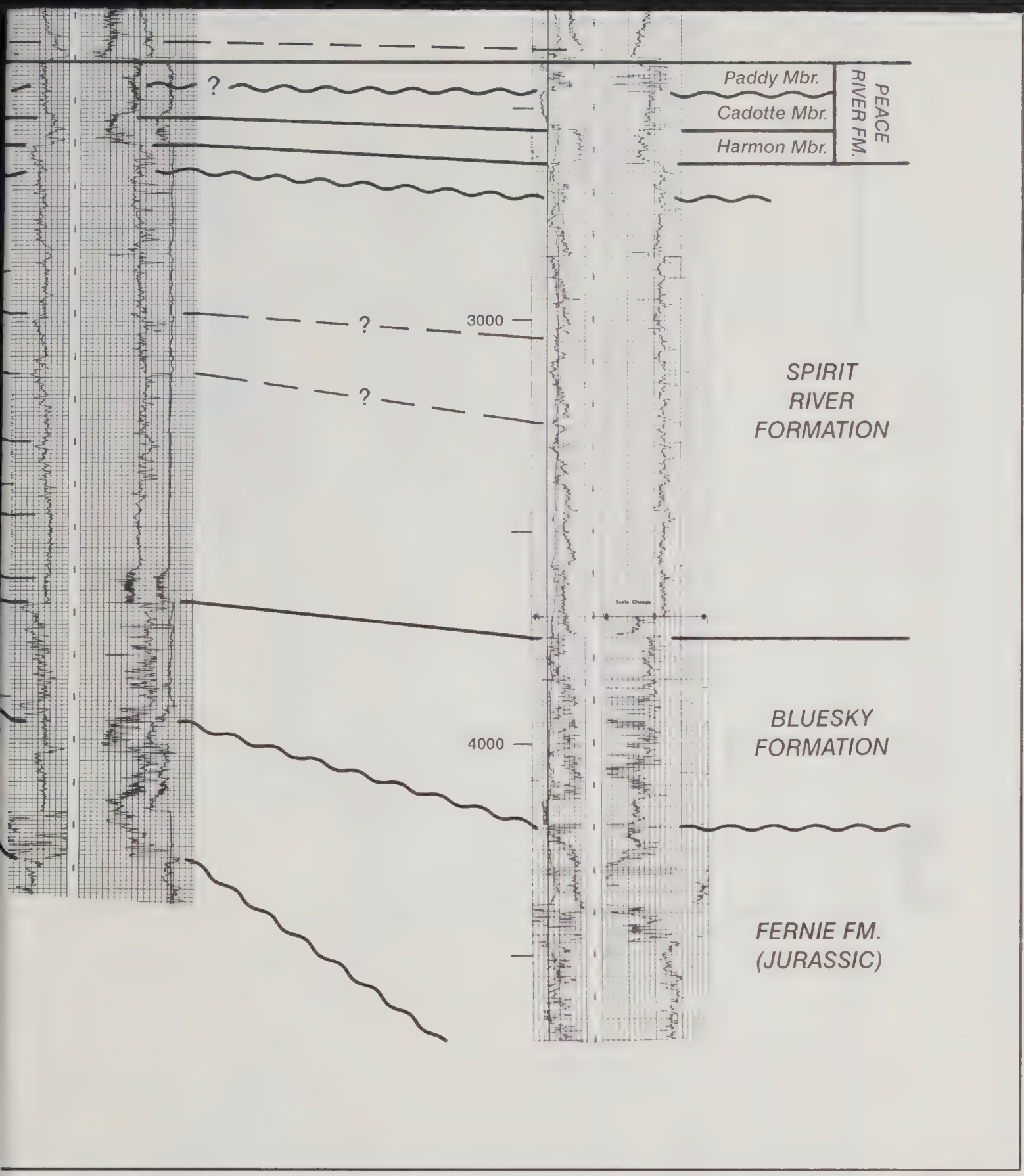

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Figures 37, 39
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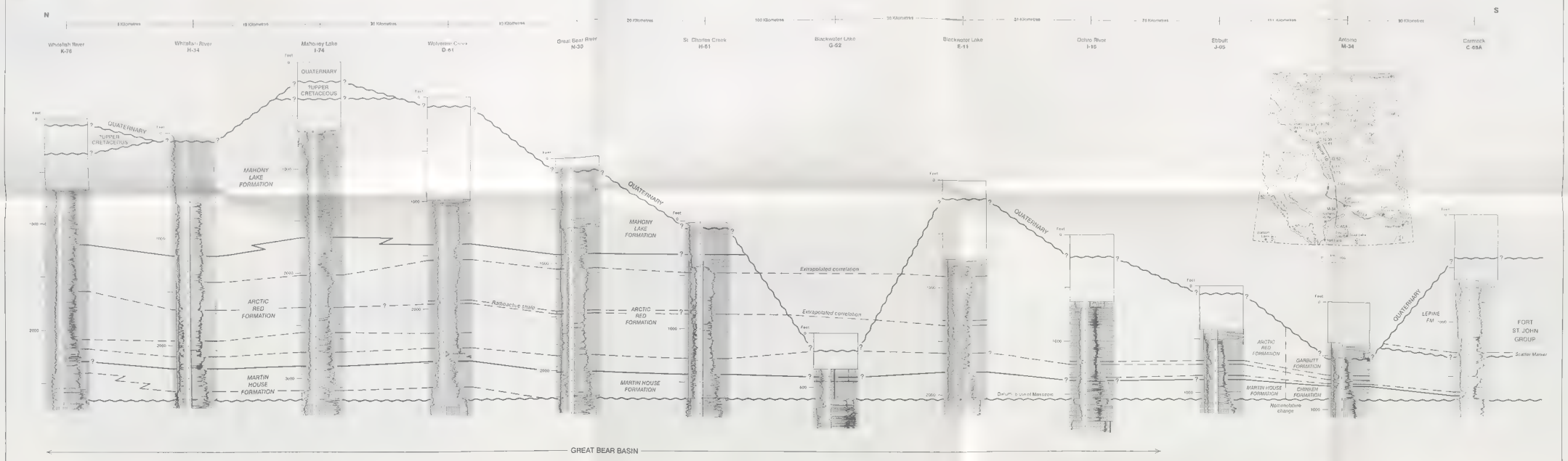

Figure 10. Log correlations in Cretaceous strata, Great Bear Plain to the western Cameron Hills: Whitefish River K-76 to Carmack C-65A.

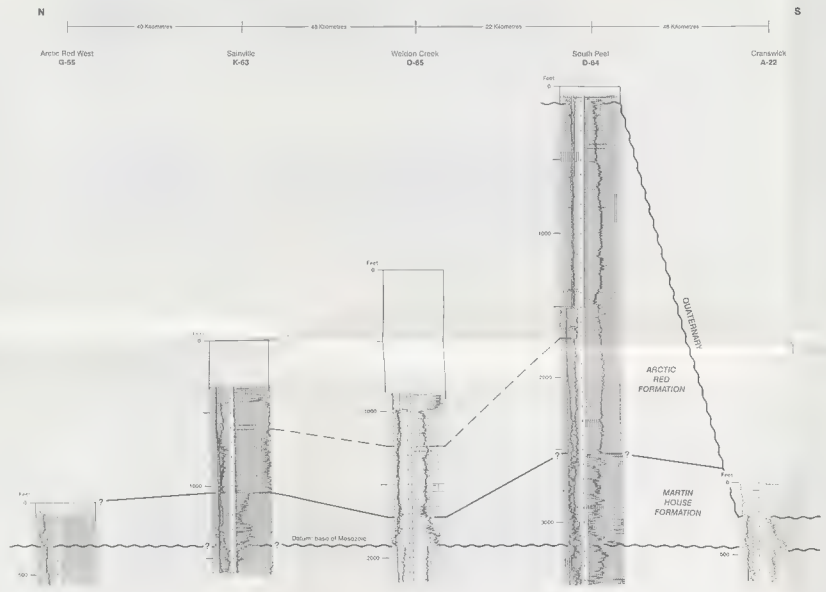

Figure 5. Log correlations in Cretaceous strata, Peel Plain and Plateau: Arctic Red West G-55 to Cranswick A-22.

LEGEND

Major unconformity
Formation boundary
Interformational correlation
Questionable interpretation ?

All logs are sonic/gamma ray except where noted

Geology by J. Bloch

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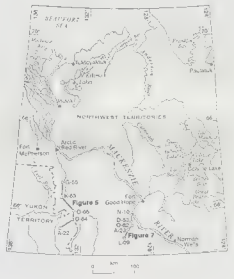


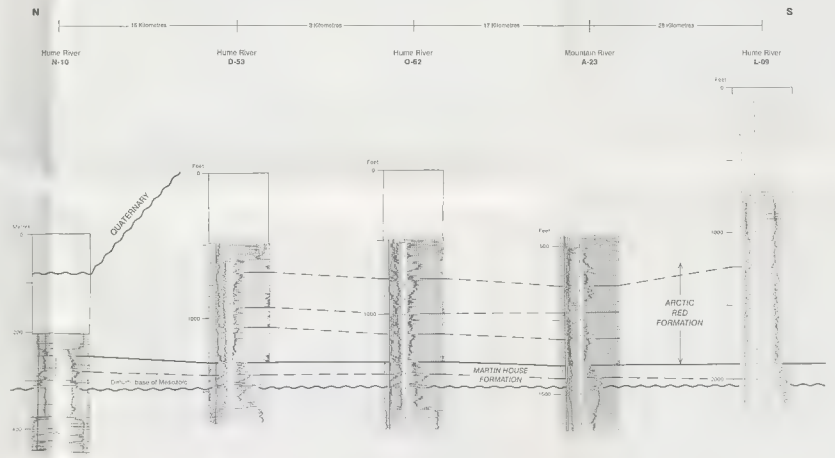
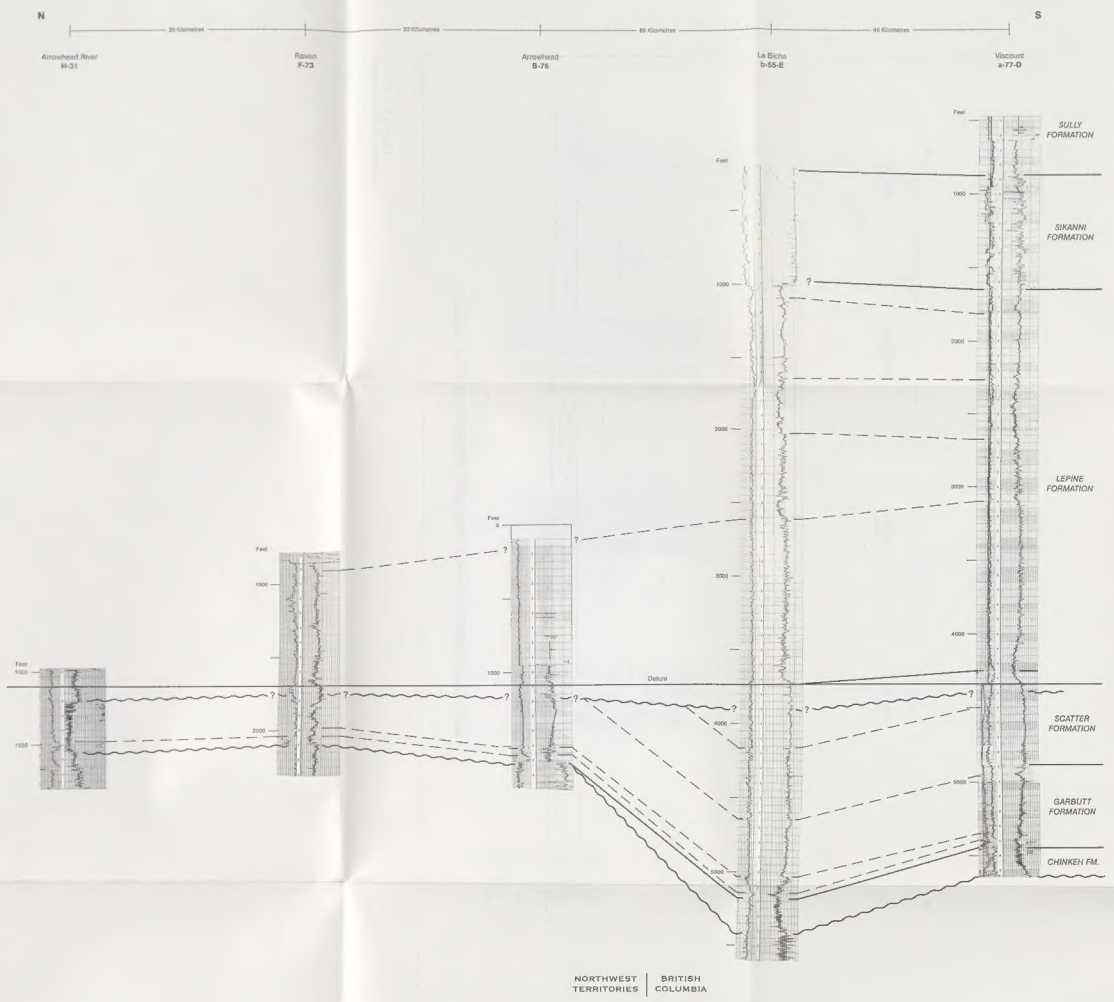
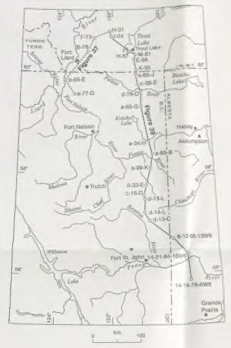


Figure 7. Log correlations in Cretaceous strata, eastern Peel Plain: Hume N-10 to Hume L-09.





LEGEND

Major unconformity
Formation boundary
Interformational correlation
Questionable interpretation ?

All logs are sonic/gamma ray except where noted

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To accompany GSC Bulletin 536 by J. Dixon

Figure 37. Correlation of Cretaceous strata in wells from the southern Northwest Territories and northeast British Columbia: Arrowhead H-31 to Viscount a-77-D.

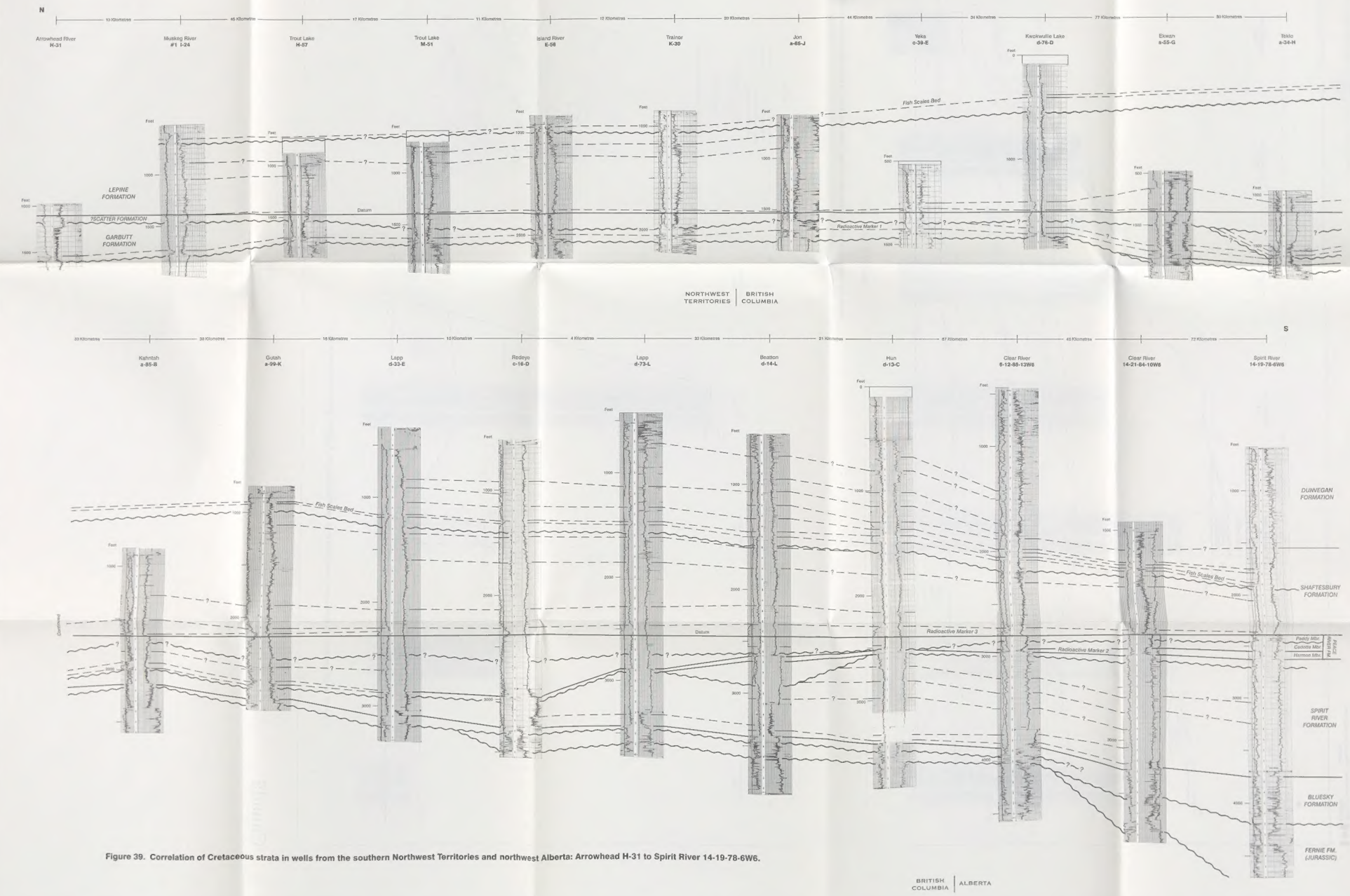

Figure 39. Correlation of Cretaceous strata in wells from the southern Northwest Territories and northwest Alberta: Arrowhead H-31 to Spirit River 14-19-78-6W6.